Ontario Round
Table on
Environment
and Economy

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de l'Ontario sur
l'environnement
et l'économie

Transportation Sectoral Task Force

Draft Report

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PREFACE

This report is one in a series prepared for the Ontario Round Table on Environment and Economy. The Round Table was established in 1988 by the Government of Ontario to create a sustainable development strategy for the province. The Honourable Ruth Grier, Minister of the Environment, is its Chair.

To assist in the creation of a sustainable development strategy, the Round Table established six task forces responsible for the Agriculture and Food, Energy and Minerals, Forestry, Manufacturing, Transportation, and Urban Development and Commerce sectors. It also set up a Native People's Circle to provide the Aboriginal perspective on sustainable development.

The sectoral task forces were charged with reporting to the Round Table on how best to begin to achieve sustainability in each sector within the context of the six principles set out by the Round Table in its **Challenge Paper**. These are:

- anticipation and prevention of environmental problems;
- the use of full cost accounting;
- informed decision-making which reflects environmental impacts and long term goals;
- living of the interest and reserving our "natural capital";
- quality over quantity; and
- respect for nature and the rights of future generations.

The Round Table also asked the task forces to consult with stakeholders in developing their overall strategy for sustainable development. Through a combination of research and formal and informal meetings with stakeholders, the task forces and the Native Circle have documented the state of each sector and the options and obstacles to sustainability, as well as their recommendations for action.

The sectoral task force reports will be fowarded to the Ontario Round Table on Environment and Economy. The final recommendations will be considered by the Round Table as it prepares a Provincial strategy for sustainable development.

October 1991

To the Reader:

The Transportation Sector Task Force was set up to examine the transportation sector and to make recommendations on implementing a sustainable development strategy to the Ontario Round Table on Environment and Economy. The members of the Task Force are:

Chair: **Dale Martin**, Councillor, Metropolitan Toronto
Members: **Judi Cohen**, Assistant Manager, Functional Design and Environmental Engineering Division
Dave Guscott, Assistant Deputy Minister, Policy, Ministry of Transportation
Phil Jessup, Director, Urban CO2 Project, International Council for Local Environmental Initiatives
Annie Labaj, National Representative, Education Department, Canadian Auto Workers
John McCullum, President, Transportation 2000/Ontario
Jim McFarland, Vice President, Environment, Imperial Oil Limited
Tayce Wakefield, Director, Public Relations, General Motors of Canada
Doreen Cachagee, Chief, Chapleau Cree, Native Circle Representative

In this report, the members of the Task Force present their views on ways that government, non-government organizations, and private industry can best promote a healthy environment and economic development in the transportation sector.

Task Force members consulted with stakeholders during the preparation of this report. They are now inviting comments on this draft report and on its recommendations. Comments received by November 8, 1991 will be taken into consideration in the final report presented to the Round Table on November 15.

The final report will be released for general public comment in December. The Round Table will consider the recommendations contained in the final report in preparing its overall strategy for sustainable development for the Province of Ontario.

Individuals, groups, or organizations who wish to comment on this draft report may do so in writing. For more information please contact the Round Table at (416) 327-2032. For long distance call collect. Please send written comments to:

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INTRODUCTION

This report of the Transportation Task Force of the Ontario Round Table on Environment and Economy describes the transportation sector in the province and outlines some of the options for a sustainable transportation strategy.

- Chapter I is a description of the transportation sector in Ontario, including the key environmental and economic issues.
- Chapter II outlines the Task Force's vision of an environmentally and economically sustainable transportation system. The elements of this system include:
  - reduction of greenhouse gas emissions;
  - reduction of ground level ozone production;
  - increased use of renewable energy sources;
  - improved energy efficiency; and
  - improvement of the province's international economic competitiveness through the development of new, state-of-the-art transportation technologies.
- Chapter III is a summary of the economic opportunities implicit in this vision.
- Chapter IV is a summary of the key actions required to achieve the vision for sustainable transportation.
- Appendix I outlines in detail the recommendations for actions towards a sustainable transportation strategy for Ontario.
- Appendix II is a transportation sector data base.
- Appendices III, IV, and V model three energy efficiency scenarios and provide quantifiable results in terms of energy efficiency and pollution reductions.

This report is not intended to be a comprehensive strategy for the transportation sector, but rather a "next steps" document which suggests some of the changes the sector must undertake to make its contribution to sustainable economic and social development.

I. THE TRANSPORTATION SECTOR IN ONTARIO

1. Sector Overview

Ontario has for many decades been the economic and industrial hub of Canada. The province's resource base includes water, minerals, forests, and wilderness in the north, and rich farmland and secondary industry in the south. Although southern Ontario makes up only 10 percent of the province by area, it contains 90 percent of the population, most of it in urban areas.

The transportation sector is a major player in the economy of Ontario, with the frequency of movement of both people and goods well above the average for the developed world. The manufacture of transportation equipment, furthermore, contributes over 30 percent of the province's exports and is Ontario's single largest manufacturing sector.

Some 90 percent of traffic in Ontario moves along a narrow transportation corridor between Windsor and Montreal which connects manufacturers, suppliers, and markets in the US as well as Canada. Links between northern and southern Ontario, in addition, provide southern manufacturers with a steady supply of raw materials, and northern residents, to a lesser extent, with manufactured items from the south.

Much of this movement relies on roads. Goods which used to be in part to meet commercial demand for just-in-time delivery. Road transport has captured much of the goods movement in this corridor. Commuters rely on road systems as well as public transit for access to urban centres. In the last ten years, the number of cars on the road has increased, while the number of passengers per vehicle has decreased. Highways in and out of larger urban areas are often clogged with vehicles carrying a single passenger. In the past few years, intercity rail service has been decreased, while air travel has increased.

Transportation in Southern Ontario can take advantage of economies of scale, especially in the densely populated and highly industrialized corridor between Windsor and the Quebec border. In this part of the province, public transit and high speed commuter train service, intercity passenger rail service and integrated road/rail goods movement are viable options when the full economic social and environmental cost of each mode is taken into account, and international transportation links are well developed.

In northern Ontario, low population density and vastly greater distances make these options unfeasible, and Northern residents rely to a greater extent on the road system for access to goods, jobs, economic opportunities, and cultural and social services--such as health care. For isolated communities, rail offers limited access and air is often the only option for long distance travel, with local needs served by small boats, snowmobiles, and even walking. Geographic isolation and greater distances in the north contribute to increased costs for transportation and for other goods and services.

2. Environmental Impacts

The transportation sector in Ontario makes a considerable contribution to environmental problems. Per capita energy consumption in the province is one of the highest in the world; the transportation sector accounts for over a quarter of this energy. It also accounts for a proportional share of the negative environmental effects of fossil fuel use, including emissions of greenhouse gases that could cause global warming, ground level ozone, and urban smog, and adverse effects on the health of humans, animals, and ecosystems.

Transportation accounts for a third or more of carbon dioxide (CO2)--a major greenhouse gas, oxides of nitrogen (NOx), and volatile organic compounds (VOC) hydrocarbon pollution, and for some two-thirds of the carbon monoxide (CO) in the atmosphere. These gases may escape from the tailpipe of all transportation modes, even during fuel refining and distribution. There are roughly 4.6 million automobiles and 1 million trucks registered in Ontario. Each automobile annually consumes an average of 75 GigaJoules of energy and emits 4.7 tonnes of CO2.

The negative environmental impacts of fossil fuel combustion, include:

Global Warming:

Climate experts predict that increased concentrations of the greenhouse gases CO2, CH4, N2O, CFCs and ozone--almost all of which are produced in part by the transportation sector--could lead to global warming with attendant damage to natural and human systems in some parts of the world.

Reduced Air Quality:

Oxides of Nitrogen (NOx) and volatile organic compounds (VOCs) contribute to the formation of urban smog and ground level ozone. These substances reduce urban air quality, cause and aggravate health problems, and reduce crop yields.

Destruction of the Upper Ozone Layer:

The transportation sector contributes chlorofluorocarbons (CFCs) to the atmosphere through leakage from vehicle air conditioning units. CFCs are strongly implicated in the destruction of the upper ozone layer which screens out cancer-causing ultraviolet rays.

Consumption of Non-Renewable Resources:

Fossil fuels are a non-renewable resources and over time will deplete. Per capita energy consumption in the province is higher than in most developed countries. A sustainable energy future for the world will require the increasing development of renewable fuels. This is important for the transportation sector in Ontario since it accounts for 72% of the province's consumption of refined petroleum products.

Other Environmental Problems:

The transportation sector contributes to environmental damage in a number of other ways. Street cars and trolley buses run on electric power partly generated by fossil fuel combustion with its own set of environmental impacts, or in nuclear plants which produce radioactive waste. Used vehicle fluids end up discarded because there is a lack of recycling alternatives. Waste products from the transportation sector--including used tires, waste oil, and vehicle bodies--are hazardous and/or take up space in landfill sites.

3. Factors Affecting Trends in Transportation

The development of the existing transportation system in Ontario has been influenced by a number of factors.

Land use policies which concentrate employment in city centres and in isolated industrial parks, and concentrate housing in sprawling suburbs increase the need for private automobiles. In Metropolitan Toronto, from 1979 to 1989, there was an estimated 78% increase in morning peak period inbound vehicle trips. Auto occupancy during this same period decreased from 1.21 to 1.19 persons per car. By the mid 1990s, estimates one source, the average Toronto commuting time will be two hours. Drastic reductions in pollution from individual automobiles have been offset by ever increasing numbers of automobiles on the road.

Regulations in the U.S. have a powerful effect on the transportation sector in Ontario. Eighty percent of the vehicles manufactured in Ontario are exported to the United States, and 80 percent of the vehicles sold in Ontario are manufactured in the U.S.

Automobile use is strongly influenced by what has been called "our love affair with the automobile". To many drivers, the automobile is much more than a means of getting from one place to another. It offers comfort, convenience, flexibility--and power, speed and status, benefits which other forms of transportation often fail to supply. It is only when gasoline prices rise or fuel supplies are threatened that consumers demand more fuel-efficient vehicles instead of increased performance.

Government subsidies have a strong influence on the transportation sector. Subsidies to roads and highways encourage the use of passenger automobiles and transport trucks. Low subsidies to railways has made rail travel relatively more expensive and less convenient.

II. THE VISION

The efficient movement of goods and people is vital to a successful modern economy. In Ontario, the transportation sector is also a major generator of economic activity and wealth. The members of this task force believe that in order to realize the goals of social equity and continued economic development, it is essential that transportation activity and production of transportation-related goods in the province increase. True economic sustainability must, in addition, take into account the real cost of transportation, including the health costs associated with air pollution, the loss of productivity due to congestion and stress, and personal injury from vehicle accidents.

The transportation sector makes a significant contribution to ground-level air pollution and to increasing concentrations of greenhouse gases in the atmosphere. For this reason, the global community has targeted changes in the this sector as a key component of improving the quality of the environment.

The members of this task force believe it is possible to follow a path that successfully responds to both challenges. The experience of Sweden and Germany suggests that sound environmental policies and practices can encourage healthy economies and sustain international competitiveness. Examples do exist, in addition, of Canadian companies which have improved their economic performance after correcting environmental problems.

The task force sees a future in which the transportation sector plays an even greater role in the economic and social life of Ontario than it does today. At the same time it believes the transportation sector can and must continue to make significant contributions towards restoring and maintaining the integrity of our environment.

The most successful economies of the future will be those that move goods and people efficiently with a minimal environmental impact. It is crucial that we chart a course for the province of Ontario that puts us on the leading edge of these developments. The intent must be to move the Ontario transportation sector forward as quickly as possible, without undermining its essential competitiveness. Change will be durable only if it brings with it economic progress and social wellbeing.

The elements of an environmentally and economically sustainable transportation strategy for Ontario include:

- reduction of greenhouse gas emissions;
- reduction of ground level ozone production;
- increased use of renewable energy sources;

- improved energy efficiency; and
- improvement of the province's international economic competitiveness through the development of new, state-of-the-art transportation technologies.

The task force agrees that a sustainable transportation strategy should include the principles of social, intergenerational and regional equity. Cost burdens of any changes made to achieve a sustainable future should not fall disproportionately on one group or region. A balance must be found between meeting environmental goals, meeting general demand for access to transportation and responding to the demands and aspirations of groups with special transportation needs.

The move to a more environmentally sustainable transportation system will require social, technological and institutional changes. These may include the development and exploitation of more environmentally benign transportation technology, and changes in the structure of cities which reduce the need for commuting. Social changes, such as the rapid rise in the use of computer technology, may change work patterns and have an impact on transportation.

The task force believes that the transformation of Ontario's transportation sector to a new order of efficiency and sustainability will be achieved through a balanced strategy of regulations, market forces, and education. Pricing and taxation which reflects the real cost of each transportation option will be an important influence on choices. A strategic approach to land use and transportation planning will be another key component of a sustainable transportation strategy, along with a streamlined environmental assessment and review process. Tools for change will likely include state-of the environment reporting and full cost accounting.

The intent must be to move the Ontario economy and transportation sector forward without undermining its essential competitiveness. There is a fine line between being on the leading edge of change, with all of its benefits, and reaching beyond what the economy and society can sustain.

III. ECONOMIC CONSTRAINTS AND OPPORTUNITIES

The production of cars, trucks, and aircraft for export are important economic activities in Ontario. A very real fear exists that tougher Ontario pollution standards could hurt the province's economic edge, at the cost of manufacturing jobs, and loss of technical expertise.

These changes, however, also provide incentives for the transportation goods sector in the province. Ontario is already an innovator in the area of alternative fuels and the development of technology for accessible transit, light rapid transit, alternatively fuelled transit vehicles, infra-red emission scanning equipment and fleet management control systems.

These areas offer opportunities to develop external markets. It is becoming more commonplace for many countries, including developing countries, to sign environmental agreements. Furthermore, other North American jurisdictions, including California, plan to implement, by the end of the decade, programs to encourage the sale of vehicles which can run on alternative fuels.

As it is becoming more and more likely that export markets will choose environmentally friendly products and technology--even at a slightly higher cost--Ontario's existing and future trade agreements should be examined for compatibility with the goals of sustainable development.

IV. GETTING TO A SUSTAINABLE TRANSPORTATION SECTOR - STRATEGIC ACTIONS

The high energy, petroleum-based, automobile-centred transportation system of Ontario is not sustainable. It exploits non-renewable fossil fuels, creates pollution and wastes, and is increasingly failing to fulfil its role of moving people and goods efficiently.

Section IV describes the elements of a sustainable transportation future for Ontario. Although there is no magic formula for getting there, this task force recommends an approach which builds on current knowledge, technology, infrastructure and decision-making processes.

Current knowledge of the state of the environment, and of the economic and environmental benefits and costs of specific actions is in some cases minimal. These existing policies and practices have, for the most part, been based on economic, technical, or operational needs, even though they do, in some cases, also have environmental benefits. In many cases, an essentially intuitive or "common sense" appreciation that some degree of environmental benefit will occur has influenced the adoption of an existing policy or practice.

The approach recommended by the task force includes:

- improving vehicle performance;
- encouraging the use of alternative and reformulated fuels;
- influencing transportation demand patterns;
- planning for sustainable transportation;
- encouraging a shift towards transportation modes involving lower energy consumption and emission levels;
- managing waste from the transportation sector;
- informing consumers, manufacturers and regulators; and
- ensuring regional and social equity.

1. IMPROVING VEHICLE PERFORMANCE

The auto industry has doubled new automobile fuel efficiency--to 8.2 L/100 km--over a ten year period. For each degree of improved energy efficiency, energy consumption and carbon dioxide are reduced in a one-to-one ratio. A doubling of fuel efficiency therefore halves CO2 emissions and energy consumption per vehicle.

Technological improvements have resulted, since 1988, in a 90% reduction in vehicle emissions (96% for hydrocarbons, 96% for CO, and 76% for NOx). Transport and Environment Canada projects that total emissions from cars will decrease by 31 to 43 percent by 2005 as newer, cleaner vehicles replace older ones on the road. The challenge, nevertheless, continues to be the development of new technologies to reduce and eliminate emissions of greenhouse gases and the precursors of low level ozone.

This task force recommends that fuel efficiency be further improved through:

- higher fuel efficiency standards for automobiles (not consensus amongst all members);
- development of fuel efficiency standards for light trucks(not consensus amongst all members);
- a scrap program for old motor vehicles;
- mandatory maintenance inspections;
- license fees based on vehicle efficiency and emissions ratings;
- a gas guzzler/sipper feebate program which provides incentives to those who purchase fuel-efficient cars (not consensus amongst all members);
- labelling the fuel efficiency of new vehicles;
- other market based approaches to reduce greenhouse gas emissions;
- improved vehicle operating practices; and
- research into oxides/nitrogen (NOx) chemistry.

2. ENCOURAGING THE USE OF ALTERNATIVE AND REFORMULATED FUELS

Alternative fuels include reformulated gasoline and diesel fuels, propane and other liquified petroleum gases, compressed natural gas, methanol, ethanol, hydrogen, and electricity produced through the use of hydraulic, nuclear, and high efficiency fossil fuels.

By switching to these alternatives the transportation sector may significantly reduce its contribution to emissions of greenhouse and other environmentally damaging gases. The task force recommendations in this area include:

- funding of an International Transportation Institute to do research and development on alternative fuels;
- a state-of-the-art analysis of alternative fuels;

- development of standards for the independent evaluation of alternative fuels;
- adoption of the Phase I of the NOx/VOC Management Plan which requires the reformulation of gasoline during the summer months to help reduce ground level ozone;
- development of a Fuels Strategy for the publicly funded transportation sector; and
- development of an Economic Instruments action plan to enhance the technical and commercial potential of reformulated and alternative fuels.

3. INFLUENCING THE DEMAND FOR AND USE OF THE AUTOMOBILE

The goal of demand management strategies is to influence people to reduce travel, to travel during of-peak hours, and to shift to more efficient modes of automobile transportation. This can be accomplished in a variety of ways:

High Occupancy Vehicle (HOV) lanes--for use during rush hour only by vehicles carrying more than four passengers--increase the average volume a highway can carry by 10 to 15 percent.

The introduction of paid parking where it was previously free, or removal of parking subsidies can reduce single-passenger driving by as much as 30 percent.

Variable pricing charges drivers of automobiles and trucks for the use of roads during peak periods and over long distances.
The use of centralized computers to control the network of traffic signals can reduce average travel time by 25 percent, delays by 15 percent, fuel use by 13 percent, and emissions by 10 percent.

Computerized traffic management systems that allows the driver, the vehicle, and the roadway to interact through electronic signals can reduce traffic congestion, total air pollution and energy consumption while allowing highways to handle up to 20 percent more volume.

Telecommuting--the movement of information instead of people--helps reduce energy use and traffic congestion, and improves air quality.

The task force suggests the following actions in the area of demand management:

- development of HOV systems;
- removal and reduction of parking incentives;
- encouragement of ridesharing;
- improvement of transportation pricing strategies;
- improvement of traffic flow;
- installation of Advanced Vehicle/Highway Systems;

- promotion of telecommunications; and
- promotion of alternative working schedules, including flexible work hours.

4. PLANNING FOR SUSTAINABLE TRANSPORTATION

Land use and urban design policies have a powerful impact on transportation demand and supply.

Lower density cities encourage higher per capita gasoline use and vice versa. At a residential density of 30-40 people per hectare a less-auto based, more transit oriented kind of urban transport tends to occur. Mixed-use areas--combining residential with commercial/industrial buildings--tend to have lower traffic and parking requirements and more open space and retail activity.

An institutional and regulatory framework that supports long range planning--based on environmentally and economically sound policies and practices--is also a vital component of a sustainable transportation strategy. An integrated official plan also requires a consistent approach to transportation planning which combines roads and transit.

The task force recommends that planning for sustainable transportation include:

- amendment of the Planning Act to require the development of long term land use/transportation plans;
- development of a growth management strategy for the Greater Toronto Area (GTA);
- economic incentives and other market forces to expand transit systems and other environmentally sustainable forms of transportation; and
- municipal transportation planning.

5. ENCOURAGING A SHIFT TO TRANSPORTATION MODES INVOLVING LOWER ENERGY CONSUMPTION AND EMISSION LEVELS

Air pollution and increasing concentrations of greenhouse gases in the atmosphere are both linked to the burning of fossil fuels. A shift to transportation modes that use less energy and create fewer emissions is a key component of a sustainable transportation strategy.

This task force believes that for passenger movement, mass transit modes--including buses, ferries, railroads, subways, rapid rail vehicles, light rail vehicles, and trolleys--are more sustainable in general than the private automobile. Mass transit can reduce congestion, emissions and energy use and contribute to sound economic development. Per passenger, mass transit vehicles, on average, emit 50 percent less CO2 than an average automobile and use 40-60 percent less energy per passenger mile.

Bicycling, too, deserves support as it is the most energy efficient mode of transport. Each person who cycles instead of taking the car avoids releasing at least 2.6 pounds of hydrocarbons, 20 pounds of carbon dioxide, and 1.6 pounds of NOx into the air per mile travelled.

The choice of freight modes is governed largely by economics. Intermodality--the combination of rail for long distance movement of bulk goods and road for short distance distribution of the same goods--would be the most sustainable option.

Actions recommended by this task force to promote a shift to more environmentally sustainable modes of transportation include:

- development of a long range, strategic plan for urban transit development in the Greater Toronto Area (GTA);
- use of the existing GTA rail network for rapid rail commuter service;
- development of high speed rail services;
- adoption of a comprehensive provincial bicycle policy; and
- promotion of an intermodal system for moving goods.

6. MANAGING WASTE FROM THE TRANSPORTATION SECTOR

The transportation sector contributes many substances to the waste stream, including: old car and tires; waste from highway and road construction; salt runoff from deicing, which runs off into waterways; and CFC's from auto air conditioning.

The task force recommends that the transportation sector:

- develop a recyclable car;
- eliminate the use of CFCs; and
- use the "Four Rs" in the manufacture and use of transportation.

7. INFORMING DECISION-MAKERS

Sound informational polices can:

- raise the level of awareness of sustainable transportation practices;
- encourage a shift in lifestyle and behaviour towards transportation choices with the lowest environmental impact; and
- identify economic benefits and opportunities inherent in environmentally sustainable transportation policies.

Accurate information is also one of the foundations of sound decision-making.

In order to raise the awareness of consumers, business, manufacturers and policy makers, the task force recommends that the provincial government:

- develop a provincial data/information base;
- develop and track indicators of sustainability
- undertake a public education campaign;
- expand formal education programs and develop materials; and
- develop a public inventory of information related to sustainable development as a rationale for all decisions in this sector.

8. ENSURING REGIONAL AND SOCIAL EQUITY

The task force recognizes that access to transportation services and facilities is essential to the social and economic well-being of every resident of Ontario.

Substantial changes to the provincial economy, and to the lifestyles of Ontario residents will likely be required to achieve sustainable development. Major changes promoted in this report include: increased use of alternative fuels; increased urban densities; incentives to transit and disincentives to the private automobile, at least in urban areas. These changes, for example, are likely to have an impact on the automotive sector, currently a major force in the provincial economy.

To ensure that such changes are accepted by individual Ontario residents, and that any trade-offs required are reasonable a sustainable transportation strategy must explicitly include information on social, economic and regional impacts.

Geographic isolation and greater distances in the north contribute to increased construction and operating costs for transportation systems, a different modal mix, and higher costs for goods and services.

Any sustainable transportation strategy developed for Ontario will likely be worked out in tandem with the over-all provincial strategy for aboriginal self-government, and recommendations made here modified as this strategy evolves. The transfer of responsibilities and authorities from the provincial government to aboriginal peoples is an essential part of the process. In the transportation sector, this may give aboriginal peoples a new degree of control over services, facilities and infrastructure which provide access to aboriginal communities and traditional areas. Potential areas for future partnerships include the planning, design, construction, operation and maintenance of transportation infrastructure and systems.

In their 1987 report, the Ontario Advisory Councils on Senior Citizens and on the Physically Handicapped concluded that "the freedom to move is life itself". "No matter where you live in Ontario" says the report, "in northern communities, on Reserves or in rural or urban communities - transportation is the essential link between home, work, medical facilities, religious centres, shopping, volunteer and social activities. Without transportation many are denied the opportunity to be independent."

Although Ontario currently provides or supports a number of transportation services and facilities for disabled persons, there is a province-wide shortage of accessible transportation at the local, regional and inter-city level--especially in Northern Ontario.

The task force recommends that social and regional equity would best be observed through:

- assessment of the benefits and costs of all components of a sustainable transportation strategy by geographic region and for special groups;
- annual reporting on the benefits and costs to northern Ontario of activities in the transportation sector;
- a comprehensive review of the transportation needs and potential for the north;
- a strategy for delivery of coordinated integrated services to the north;
- investigation into ways of increasing government support for and adding local value to the northern economy;
- review and amendment of legislation pertaining to aboriginal peoples and transportation;
- assessment of the potential for government/aboriginal partnerships in this sector;
- promotion of training in the transportation sector;
- identification of the options for a new aboriginal transportation initiative;
- review and amendment of criteria for government funding;
- development of a process for considering proposals and initiatives from aboriginal peoples;
- meeting the demands for accessible transportation;
- development of programs and financial support mechanisms; and
- development of procedures for ensuring coordination of services.

Appendix

APPENDIX I: DETAILED TASK FORCE RECOMMENDATIONS

1. IMPROVING VEHICLE PERFORMANCE

1.1 Improving Fuel Consumption Standards

The Corporate Average Fuel Consumption (CAFC) program--in place in Canada since the late 1970s--is designed to improve fuel consumption in new automobiles through design changes and technological improvements. On average, the auto industry has exceeded the CAFC standards, even though the program is a voluntary one, and doubled new automobile fuel efficiency--to 8.2 L/100 km--over a ten year period. Since 1986, fuel economy gains have levelled out. Because the real price of gasoline was relatively constant from 1977 to 1990, the public has tended to demand improvements in vehicle performance rather than improvements in fuel efficiency.

For each degree of improved energy efficiency, energy consumption and carbon dioxide are reduced in a one-to-one ratio. A doubling of fuel efficiency therefore halves CO2 emissions and energy consumption per vehicle.

Recommendation

1.1.1 **That the Provincial government encourage the Federal Government to implement separate CAFC standards for light trucks and vans.**

1.1.2 **That the Provincial Government encourage the Federal Government to work with vehicle manufacturers to investigate the feasibility of increasing the corporate average fuel consumption standard from 8.6 l/100 km to 6.7 l/100 km**

NOTE: There is not complete consensus of the task force members on this recommendation. General Motors strongly opposes the implementation of separate CAFC standards for light trucks and vans, and increasing the corporate average fuel consumption standards to 6.7 l/100 kilometres for several important reasons:

- The CAFC program disadvantages full-line manufacturers who employ 500,000 people directly and indirectly in Ontario, without challenging the major automotive importers to make significant improvements in the fuel economy of the products they offer for sale in Ontario
- CAFC does not in any way encourage consumers to alter their purchasing

behaviour in favour of smaller cars. For example, although the Chevrolet Sprint/Pontiac Firefly was the most fuel efficient vehicle for sale in Canada in 1991, it captured only 2.5% of all vehicle sales, and the entire economy market segment captured only 15% of all new car sales.

- Because improving the fuel efficiency of new cars makes them cheaper to operate, studies indicate that people tend to travel more miles, offsetting the technological improvement in the automobile.
- There is no evidence to suggest that a standard of 6.7 l/100 kilometres is technically feasible.
- According to a recent study by Charles River Associates of the U.S. CAFE program which is virtually identical to the Canadian CAFC program, "CAFE standards are an expensive way of reducing petroleum consumption and carbon dioxide emissions; a number of alternative policies are available that will achieve the same policy objectives at substantially lower cost... Under assumptions about CAFE that represent most likely conditions, a 40 mpg CAFE standard would cost annually about $15 billion more than the lowest-cost policies." The study concludes that "A combination of transportation management policies and energy tax increases would be significantly less costly than higher CAFE standards in reducing petroleum use and CO2 emissions."

1.1.3 **That producers of transportation equipment continue to be challenged to improve the fuel efficiency of their products.**

1.2 Improving Vehicle Emission Standards

Automobile manufacturers have made significant improvements in tailpipe emissions, in particular from cars and light duty trucks. Technological improvements have resulted, since 1988, in a 90% reduction in vehicle emissions (96% for hydrocarbons, 96% for CO, and 76% for NOx). The Federal government, which has jurisdiction in this area, is phasing in new tailpipe emission standards, similar to those in the U.S., which require an additional one percent reduction in hydrocarbon emissions and a ten percent reduction in NOx emissions between 1994 and 1996.

Transport and Environment Canada projects that total emissions from cars will decrease by 31 to 43 percent by 2005 as newer, cleaner vehicles replace older ones on the road. Total emissions from all on-road vehicles are projected to decline by 15 to 38 percent in the same period, even with more vehicles on the road and more miles travelled.

The challenge, nevertheless, continues to be the development of new technologies to reduce and eliminate emissions of greenhouse gases and the precursors of low level ozone.

Recommendation:

1.2.1 That the Provincial government support new vehicle emission standards for light duty vehicles which will be phased in over the period 1994-1996 by the federal government. In addition, the provincial government should encourage the federal government to pursue additional reductions, in line with U.S. plans, that are consistent with Canadian conditions.

1.3 Scrapping Old Cars

A study of carbon monoxide (CO) emissions from vehicles driving along Toronto's Don Valley Parkway revealed that 10 percent of the automobiles surveyed produced close to 50 percent of the total emissions, with older autos tending to be the worst offenders. A California pilot program which provided a $700 cash incentive for scrapping old cars was successful in removing 8,376 pre-71 vehicles from the road and avoiding an estimated 10.7 million pounds of air pollutants.

Recommendation

1.3.1 That the Provincial government develop and implement an incentive program for scrapping old vehicles in cooperation with Ontario's petroleum industries, vehicle manufacturers and steel recyclers.

1.4 Improving Maintenance

The University of Denver used infra-red sensing to study carbon monoxide (CO) emissions from vehicles driving on Toronto's Don Valley Parkway. Ten percent of the vehicles surveyed produced close to 50 percent of the total emissions, with high polluting cars falling into every age category.

Proper vehicle maintenance would not only reduce these emissions, it would result in fuel savings and lower warranty repair costs for vehicle manufacturers. Mandatory inspections could be carried out on an annual or bi-annual basis when vehicle license plates are renewed. Furthermore, program costs could be reduced by the development of a complementing mobile, on-road infra-red sensing program for carbon monoxide and other tailpipe emissions and contaminants.

Recommendations:

1.4.1 That the Provincial government immediately establish in-use vehicle

inspection/maintenance programs, along with enforcement measures, for all transportation modes. The programs should be designed in cooperation with vehicle manufacturers and the petroleum industry, and take maximum advantage of existing infrastructure to minimize costs.

1.4.2 **That the Provincial government, vehicle manufacturers and the petroleum industry, as part of the inspection/maintenance program, fund a pilot program for the development of a mobile on-road infra-red vehicle emission sensing system.**

1.5 Adjusting License Fees to Reflect Vehicle Efficiency

At present, owners of vehicles in the same class pay the same annual license fee, regardless of the environmental cost of keeping the vehicle on the road.

Recommendation

1.5.1 **That the Provincial government institute a system of license fees that is based on a vehicle's rated fuel efficiency and emission levels.**

1.6 Influencing Purchasing Decisions: The Gas Guzzler/Sipper Feebate Program

Ontario's gas guzzler tax program taxes passenger and sport utility vehicles that have fuel economy ratings of 6.0 l/100 km on a sliding scale from $ 75 for passenger vehicles with rating of 6.0-8.9/100 km to $ 7,000 for passenger vehicles over 18.0 l/100 km. A rebate of $ 100 is applied to passenger vehicles with ratings of less then 6.0 l/100 km. The province could further encourage consumers to buy cleaner, more fuel efficient cars and light trucks by strengthening this program. For example, Ontario could offer a sales tax rebate to consumers who buy autos and light-duty trucks with lower-than-average CO2 emission levels. The funds could come out of sales tax surcharges levied on consumers who purchase vehicles with higher-than-average emission levels. Another approach is that proposed for California. The DRIVE+ program (Demand Reductions in Vehicle Emissions Plus improvements in fuel economy) will allow the state to set annual goals for all emissions--including CO2--for all new vehicles, and to adjust incentives to achieve these goals.

Recommendation:

1.6.1 **That the Province modify its gas guzzler tax to a DRIVE+ program which sets annual goals for vehicle emissions and provides larger rebates to consumers who purchase vehicles with lower-than-average emissions.**

NOTE: There is not complete consensus of the task force members on this recommendation. The representative of General Motors does not support it for the following reasons:

- it addresses only new vehicles, not the majority of vehicles on the road which are comparatively less energy efficient;
- it does not account for vehicle function or utility nor whether it is used for car pooling;
- because the Ontario new car market is already skewed toward small cars, it would require such a high tax on the relatively few larger cars that no one would purchase them, meaning funding for the program from general revenues; and
- it encourages consumers to purchase imported products (the GeoMetro is the only small car manufactured in North America) at the expense of Canadian jobs.

1.7 Influencing Purchasing Decisions: Labelling New Vehicles

Labels on new cars which identified the vehicle's emission levels would provide consumers with critical information on which to make purchase decisions. They would also reinforce and explain to consumers the rationale for the gas guzzler/sipper feebate program.

Recommendations:

1.7.1 **That the Provincial government require labels on all new vehicles sold in Ontario, listing estimated emissions if the vehicle travels 20,000 km/year at a specific speed and with a specific load.**

1.7.2 **That the Federal government develop and expand consistent national standards for vehicle design relating to the results of emissions testing, and require manufacturers to carry out specified minimum testing procedures, to which such labelling could be adapted.**

1.8 Other Market-based Approaches to Reducing Greenhouse Gas Emissions

To the extent that the costs of environmental degradation for the most part are not included in the costs to consumers for transportation equipment, fuels and practices, then market barriers exist to the development of a more sustainable transportation sector. We need to examine sensible ways to remove these barriers in order to harness the power of market forces to effect change.

A broad based tax levied on all fuels in relation to their carbon content is one way to reflect the environmental costs associated with combustion. Such a tax would raise the price of fossil fuels, support the use of alternative fuels, and promote more energy efficient technologies.

The tax could be adjusted to encourage the reduction of emissions to levels deemed necessary from a scientific and economic standpoint. Depending on the level of taxation, significant revenues could be generated. These revenues could be used to reduce any distributional burden imposed by the tax; fund transportation alternatives such as public transit, high occupancy vehicles, and alternative fuels; and stimulate economic growth to offset the carbon tax effect.

Recommendation

1.8.1 That the Provincial and Federal governments undertake, jointly or independently, within their respective jurisdictions, an econometric analysis of various market-based approaches, such as carbon taxes or other price-based approaches and emissions trading schemes or other quantity-based approaches to reduce CO2 emissions and other greenhouse gas emissions from the transportation sector, considering such issues as: elasticity of demand for various energy uses; the level of prices or extent of trading schemes required to achieve real gains; regional, social and sectoral impacts; implications for the balance of trade and competitiveness by economic sector; possible phase-in approaches; global vs. regional applications; and alternative strategies for allocating the revenues generated, including deficit reduction, new environmental programs, and reductions in personal, corporate or consumption tax rates.

1.9 Improving Operating Practices

The Ontario Ministry of Transportation conducts research and provides vehicle operators with information on fuel efficient driving practices, vehicle selection, maintenance and fleet operations. Just by following the recommended measures, operators can reduce fuel consumption and emissions by ten to fifteen percent.

At the height of the 1973 oil crisis, the U.S. Congress reduced the national speed limit to 55 mph (89 kph) in order to conserve energy. The benefits of this move were calculated in 1985 to be $3 billion a year in fuel savings and $195 million in the direct costs and $3.3 billion in the indirect costs of motor-vehicle accidents (Gordon, 1991). Increasing passenger speed from 50 to 60 mph reduces fuel efficiency by 20 percent. As much as 30 percent is lost when speed increases from 55 to 75 mph (Gordon, 1991).

Recommendation

1.9.1. That the provincial and municipal levels of government develop mechanisms to ensure that speed limits on provincial highways and municipal roads are enforced through higher fines, better policing and posted signs indicating levels of fines.

1.10 Investigating NOx Chemistry

Although nitrous oxides (NOx) contribute to the formation of poisonous ground level ozone, they can also inhibit its development. The specific action of NOx depends on the atmospheric mix of NOx and hydrocarbons. At present, not enough is known about this atmospheric chemistry to justify controls.

Recommendation

1.10.1 That further research be undertaken on the NOx paradox in order to develop an appropriate NOx emissions strategy.

2. ENCOURAGING THE USE OF ALTERNATIVE AND REFORMULATED FUELS

Alternative fuels include reformulated gasoline and diesel fuels, propane and other liquified petroleum gases, compressed natural gas, methanol, ethanol, hydrogen, and electricity produced through the use of hydraulic, nuclear, and high efficiency fossil fuels.

Some of these alternatives offer the promise to reduce greenhouse gas and other harmful emissions over the full life cycle of these fuels.

Barriers and concerns which must be addressed if the promise of reformulated and alternative fuels is to be realized include:

- lack of information about the real, cradle-to-grave environmental impacts of all fuels;
- unanswered technological questions, including questions about engine design and the combustion process;
- uncertainty about the long term supply of alternative fuels;
- lack of an infrastructure to produce and distribute alternative fuels;
- market barriers, including the need for a quick payback on investment in new or retrofitted vehicles;
- consumer inertia; and
- supply cost advantages of gasoline and diesel fuels, at least in the foreseeable future. An independent study found that given current technology, in terms of life-cycle supply costs, excluding taxes or subsidies, no alternative or reformulated fuel can effectively compete with gasoline or diesel fuel.

These concerns can be partially offset by opportunities in the alternative fuel sector.

The application of full cost accounting to the cost of fuel, for example, is likely to have an impact on the transportation fuel mix. When the full cost of oil, including health and environmental effects, is taken into consideration, the cost of alternative and reformulated fuels could be more competitive.

Gasoline and diesel fuels have infrastructure, cost, safety and convenience advantages that can be built upon to contribute to solutions. Reformulated fuels, in particular, offer emission reductions, low cost, safety, and convenience, while building on existing infrastructure.

Some alternative fuels--including propane and compressed natural gas--already have important market niches. Demonstration of technology for vehicles powered by other fuels such as methanol and electricity are well advanced. The most promising short-term alternative fuel is compressed natural gas, already available for most motor vehicle applications. However, the use of electricity to increase the gas pressure to storage pressure and the vehicle efficiency, must be considered. The most promising long-term alternative is fuel cells which can generate electricity from an array of fuels, including natural gas, hydrogen and biomass, and produce virtually no emissions.

The development of alternative fuels and technology for export as well as domestic consumption offers the province economic opportunities in an area where there is already some expertise. In 1975, the Ontario Ministry of Transportation (MTO) initiated, in cooperation with industry, energy users, research foundations, and universities, a program to encourage the introduction of propane, natural gas, and methanol in Ontario. There are at present 85,000 propane-fuelled and 9,000 natural gas fuelled vehicles in Ontario.

MTO supports the use of propane, natural gas, and methanol in transit buses. Demonstrations, in Toronto, Hamilton, Mississauga, and Windsor, will provide information on the environmental and economic benefits of buses fuelled by natural gas and methanol. The province is also supporting the development of a hybrid electric/natural gas powered bus. Appendix IV is an analysis of the impacts on energy consumption and emissions of switching from diesel buses to electric buses powered from gas fired gas turbines in combined cycle.

General Motors of Canada with the federal government are testing variable fuel Chevrolet Luminas, which can automatically sense and operate on any combination of fuels from 100% gasoline to 85% methanol.

The Federal/Provincial NOx/VOC Management Plan identifies measures to reduce ground level ozone. Ground level ozone, a contributor to smog, is produced by a series of chemical reactions in sunlight between oxides of nitrogen (NOx) from burning fossil fuels and volatile organic compounds (VOC) found in solvents and other substances.

The NOx/VOC Management Plan identifies measures to reduce VOC emissions including vapour recovery for storage tanks and transfer stations for gasoline and other volatile liquids; and the reformulation of gasoline with lower vapour pressure during the summer month. It also encourages modal switch opportunities.

Recommendations - Information/R&D Measures

2.1 That the provincial government, in partnership with motor vehicle manufacturers, engine manufacturers, petroleum industry and alternative fuels suppliers, fund an International Transportation Institute for further

research and development of reformulated and alternative fuels technology as well as alternative vehicle technology and the establishment of a standard for independent evaluation of alternative technologies.

2.2 That the provincial government lead the development of a comprehensive, state of the art analysis of all of the environmental benefits, costs, and technology development opportunities associated with reformulated and alternative fuels that can be used as:

- a chartering document for a new International Transportation Institute (Rec. 2.1), and
- a source/user guide for municipalities and the public to guide actions, particularly in the near term, associated with demonstration projects and consumer behaviour.

Recommendations - Regulatory Measures

2.3 That the provincial government adopt the Phase 1 initiatives in the CCME's NOx/VOC Management Plan which requires the reformulation of gasoline with lower vapour pressure during the summer months to help reduce ground level ozone for problem areas in the province. The plan will also require a reduction in evaporative emissions from gasoline during distribution at gasoline storage and transfer depots and in delivery to service stations.

2.4 That the provincial government, in conjunction with municipal governments, develop a Transportation Fuels Strategy for the publicly funded transportation infrastructure in the province including bus, rail, and road, with due recognition to environmental and economic considerations.

Recommendations - Economic Measures

2.5 That the provincial government, in conjunction with key stakeholders, lead the development of an Economic Instruments action plan that will enhance the technical and commercial potential of reformulated and alternative transportation fuels in the province.

3. INFLUENCING THE DEMAND FOR AND USE OF THE AUTOMOBILE

Historically, transportation planning has taken projected demand as a given and attempted to satisfy it. In a sustainable context, the goal of demand management strategies is to influence people to reduce travel, to travel during of-peak hours, and to shift to more efficient modes of transportation, including pooling.

3.1 Developing High Occupancy Vehicle (HOV) Systems

These systems are lanes designated only for vehicles with carrying greater than four people. They are designed to reduce highway congestion and travel time for buses, carpools and vanpools. A well-designed HOV lane with adequate support services, including an active ridesharing program, can carry as many people as four general-purpose highway lanes. HOV use is considered successful if it increases the average volume a highway can carry by 10 to 15 percent. Appendix V is an analysis of the implications for energy consumption and emission levels of a switch from single occupancy vehicles to vans carrying eight passengers. In concludes that if 33% of one driver auto km/a could move to eight passengers vans, 2.581×10^6 MT of urban CO_2 would be offset by an additional 6% change to vans.

Recommendations

3.1.1 **That the Provincial government, in cooperation with the municipalities of the Greater Toronto Area (GTA), develop a comprehensive High Occupancy Vehicle (HOV) system of dedicated right-of-ways and parking lots for the GTA as part of an overall urban land use and transportation strategy.**

3.1.2 **That the Provincial government develop a program for enforcement and monitoring of the HOV policy.**

3.2 Reducing Parking Incentives

Studies show that low cost parking increases auto use. By either introducing paid parking where it was previously free, or removing parking subsidies, municipalities can reduce single-passenger driving by as much as 30% (Gordon, 1991).

Currently in Ontario, employees are not taxed on parking benefits provided by their employers. They must, however, report transit passes provided by their employers as a taxable benefit. Employers, furthermore, can deduct parking maintenance and operating costs for tax purposes.

Some municipalities have relaxed parking requirements in local zoning bylaws in return for support from developers and employers for alternative transportation strategies. Sacramento, California, for example, has reduced parking requirements by five percent when bicycle facilities are provided, by 15 percent for marked rideshare parking spaces, and by 60 percent for transit-pass subsidization (Gordon, 1991).

Reductions in parking facilities offer economic opportunities. One above ground space costs up to $18,000 to build; underground parking costs even more. Land not devoted to parking can be used to generate revenues in other ways.

Recommendations

3.2.1 That municipalities investigate opportunities to implement the following congestion/parking mechanisms, and the Provincial government, through moral and financial support, encourage municipalities to:

- **extend no-parking restrictions during rush hours**
- **increase parking fees in downtown urban areas**
- **provide preferential HOV parking location and rates in municipally operated parking lots**

3.2.2 That the Federal government amend the Tax Act to make employer subsidized parking a taxable benefit.

3.3 Encouraging Ridesharing

After walking and bicycling, ridesharing is the most energy-efficient form of passenger. It reduces per capita energy consumption, greenhouse gas emissions, vehicle miles travelled and pollution. Ridesharing can also be an effective means of serving low-density development not well suited to transit.

Programs range from van pool programs organized by employers to casual carpools. Employers can boost rideshare participation rates by guaranteeing emergency taxi and ride-home services.

The Ontario Ministry of Transportation (MTO) has developed a Share-A-Ride Program which offers commuters information and computerized ride-share matching. MTO operates a network of car-pool parking lots at highway interchanges and in some urban areas. Metro Toronto is developing a strategy for an Area-Wide Ridesharing Centre, expected to be operational by early 1992.

Recommendations

3.3.1 That the Provincial government, municipal governments and large and medium size employers, ideally in partnership, establish comprehensive rideshare programs for their employees.

3.3.2 That the Federal government undertake similar initiatives for its offices and employees in Ontario.

3.3.3 That the Provincial government and municipal governments, preferably in partnership, encourage employers, through a communications campaign, to provide employee rideshare programs.

3.3.4 That the Provincial and municipal governments, preferably jointly, encourage the development of community based ridesharing through a public education campaign.

3.3.5 That where a municipality conducts a rideshare promotional campaign which is complementary to, but does not duplicate provincial efforts, this campaign be eligible for provincial subsidies as an integral part of the municipal transportation operation.

3.4 Improving Transportation Pricing Strategies

Variable pricing charges drivers of automobiles and trucks for the use of roads during peak periods and over long distances. U.S. studies show, for instance, that at present heavy trucks do not pay their fair share of the capital and maintenance cost of roads. No such study has yet been done in Canada based on Canadian conditions which are far more robust. A variable pricing strategy also charges users of mass transit higher prices for travelling during peak periods in the peak direction of travel and over longer distances. Since transit fares are fairly inelastic, small increases in fares for peak and longer distances travel should not negatively impact on ridership. However, lower offpeak and shorter distance trip fares would reduce costs to those able to utilize them.

Road pricing strategies are used in a number of cities around the world. In Stockholm, drivers entering the City Centre must buy a $56 monthly pass. Revenues from pass sales are used to improve public transit, cycling and pedestrian facilities. Hong Kong tested an electronic scanning system that automatically billed car owners for using certain streets. Drivers in Holland purchase travel kilometres in the form of "smart cards", which are attached to the windshield of each vehicle. Highway scanners read the cards and automatically deduct the number of kilometres travelled. If the card reads empty, the license plate is photographed and a bill is sent in the mail. Automated toll collection systems are being installed on highways throughout the U.S.

Ontario drivers currently pay for vehicle insurance on an annual, fixed-fee basis. California is considering a Pay-as-you-drive (PAYD) program in which drivers pay for insurance according to the distance a vehicle travels. Studies suggest a PAYD program could reduce vehicle travel by up to 15 percent in the short term and 40 percent in the long term. (Gordon, 1991).

Although variable pricing does not deter people from essential travel, such as commuting to work, it is an efficient way to match transportation supply with demand. Any disproportional economic burden placed on those with lower incomes can be corrected with income-tax credits other forms of economic compensation.

Recommendations

3.4.1 That the Provincial government institute a Pay-as-you-drive program for vehicle insurance.

3.4.2 That the Provincial government, in cooperation with municipalities, institute a system of electronic road pricing and automated toll systems.

3.4.3 That the Provincial government undertake a study of goods movement by road to assess the impact on roads for each class of user by weight, load, and distance. This study would go towards the development of a weight/distance tax and fuel tax rebate/subsidy that would assess heavy trucks their share of road costs.

3.4.4 That the Provincial government require local transit authorities to institute time-of-day and distance pricing for transit fares.

3.5 Improving Traffic Flow

Many municipalities use centralized computers to control the network of traffic signals and the efficiency of vehicle movement. These systems can reduce average travel time by 25 percent, delays by 15 percent, fuel use by 13 percent, and emissions by 10 percent (Gordon, 1991).

Recommendation

3.5.1 That the Provincial Government assist municipalities with chronic existing or developing traffic congestion problems to:

- **develop or improve standards for the efficient design and operation of major local roadway networks; and**

- **install or upgrade traffic management systems to promote and maintain efficient traffic flow.**

3.6 Installing Advanced Vehicle/Highway Systems (AVHS) or Intelligent Vehicle Highway Systems (IVHS)

An IVHS is a computerized traffic management system that allows the driver, the vehicle, and the roadway to interact through electronic signals. These systems help reduce traffic congestion, total air pollution and energy consumption while allowing highways to handle up to 20 percent more volume (Gordon, 1991).

In Ontario, the Ministry of Transportation (MTO) is developing a number of traffic management programs, including a pilot system of freeway traffic management (AVHS) currently operating on the Metropolitan Toronto section of Highway 401.

MTO is also developing IVHS systems designed to help improve the flow of traffic, provide drivers with information on road conditions and traffic flow, speed up the movement of vehicles through inspection or toll stations, and even take partial or total control of a vehicle from the driver.

Recommendations

3.6.1 That the Provincial government continue development and monitoring of its AVHS system and expand it to other provincial highways.

3.7 Promoting Telecommuting

Telecommuting is the movement of information instead of people. It involves using electronic communications--FAX machines for example--instead of going to the office, to school, or to the bank. It helps reduce energy use and traffic congestion, and improves air quality. and easing congestion.

In a four-year pilot project, the state of California found that employees who worked at home on designated days were more productive and stayed in their jobs longer. The pilot will be extended to more jurisdictions; by 2000, a predicted 12 percent reduction in work-related travel through telecommuting could reduce area-wide emissions by 2 percent (Gordon, 1991).

Recommendations

3.7.1 That municipal governments and the Province initiate, monitor, evaluate, and report upon pilot telecommuting programs for selected public sector employees.

3.7.2 That the Federal government carry out a similar program for its offices and employees in Ontario.

3.7.3 **That private sector employers be encouraged to participate in similar efforts, and to advise the Round Table of their telecommuting activities/experiences.**

3.7.4 **That the Provincial government require local municipalities to review their zoning bylaws and remove any barriers to work-at-home activities which do not conflict with residential uses with respect to noise, parking, etc.**

3.8 Promoting Alternative Work Strategies

Strategies which allow groups of employees to stagger the times at which they start and finish work, which allow individual employees some choice in planning their own work schedule, and which allow employees to put in a full week of work in less than five days can all help shift travel demand to less congested, off-peak periods.

Recommendation

3.8.1 **That municipal, provincial and federal government offices in Ontario adopt new programs, or expand existing programs, of alternative work schedules for their employees. Such programs would include flexible work hours, staggered work hours, and compressed work weeks.**

3.8.2 **That private sector employers be encouraged to adopt similar programs for their employees.**

4. PLANNING FOR SUSTAINABLE TRANSPORTATION

Land Use Planning

Land use and urban design policies have a powerful impact on transportation demand and supply. A study of the relationship between land use, public transit infrastructure, and energy consumption in 32 cities around the world found that:

- lower density cities encourage higher per capita gasoline use and vice versa;
- building more roads to solve congestion problems may only lead to greater auto dependence, congestion, and higher levels of gasoline consumption;
- limiting new road supply may encourage people to switch to public transit, but may also drive away business;
- rapid rail may the only way that public transit can really compete with the private automobile;
- at a residential density of 30-40 people per hectare a less-auto based, more transit oriented kind of urban transport tends to occur (Newman and Kenworthy).

Other studies have found that mixed-use areas--combining residential with commercial/industrial buildings--tend to have lower traffic and parking requirements and more open space and retail activity.

Under existing official plans, the review process for new developments tends to emphasize conformity with land use policy over support for environmental considerations. By placing priority on environmental issues, the goals of sustainable development would be better served. Official plans which lay out specific environmental goals--such as pollution reduction or increased energy efficiency--would encourage private sector developers to integrate these goals up-front in the planning process in exchange for faster approvals.

An institutional and regulatory framework that supports long range planning--based on environmentally and economically sound policies and practices--is also a vital component of a sustainable transportation strategy. Existing land use plans deal primarily with local concerns, and tend to ignore cross-jurisdictional issues such as wetlands management. In order to ensure that land use planning deal with such cross-jurisdictional issues, the province needs an integrated official plan or a set of guidelines for official plans. This will likely require greater involvement by the Province in the planning and policy development process, a shift towards centralized planning, and an unprecedented level of cooperation among agencies and interest groups.

Transportation Planning

An integrated official plan also requires a consistent approach to transportation planning which integrates roads and transit. Such an approach should assess the efficiency and role of each network component. Control of transportation funding, in addition, should be distributed over all levels of government. The province would then ensure that projects funded meet overall sustainability requirements, while municipalities would ensure that funding goes towards transportation that meets local needs. The development of comprehensive transportation plans which recognize environmental considerations and are supported by official plans would also streamline the environmental assessment process for transportation initiatives.

Planning for the Greater Toronto Area

Almost half the population of Ontario lives in the Greater Toronto Area (GTA). Growth and development in this area will have an enormous impact on emissions and energy use in the transportation sector. Metro Toronto has recommended that the Provincial government impose a one year freeze on development outside the built-up areas of the Toronto Urban Centred Region. During this time permanent controls for urbanization could be developed and introduced.

Recommendations

4.1 **That the Provincial government amend the Planning act by 1993 to require the development of long term land use/transportation plans that incorporate the following:**
- **increasing residential and employment densities;**
- **intensification of land use;**
- **protecting agricultural land and the rural economy; and**
- **front end transit and pedestrian planning which maximizes pedestrian and transit access.**

4.2 **That the Provincial government re-examine the Greater Toronto Area (GTA) plan and scenarios, and develop a growth management strategy that reduces dependence on the automobile. This strategy would incorporate:**
- **intensification of land use**
- **increased population and job densities (up to residential densities of 4000 persons/square kilometre);**
- **increased population and job densities (up to residential densities of 6000 persons/square kilometre) at existing and proposed transit nodes;**
- **increased mixed use development;**
- **the preservation of agricultural land and the rural economy; and**
- **a significant expansion of rapid transit.**

4.3 That the Provincial government develop incentives and other market forces for transit, including:

- density bonuses along transit routes; and
- a stipulation that transit development should lead land development.

4.4 That the Provincial government institute development incentives and other market forces which encourage a modal shift for work related trips to more environmentally acceptable forms of transportation, including

- reduced parking in exchange for bicycle facilities, marked car/van pool spaces and/or transit passes for tenants; and
- preparation of ten year trip reduction plans for development, that include personalized ridesharing assistance, shuttle van services, transit pass subsidies, etc.

4.5 That the Provincial government require municipalities to undertake site specific transportation planning which includes:

- establishment of a transportation coordinator;
- incentives for ridesharing; transit, bicycling, and alternative work schedules; and
- disincentives for automobile parking.

5. ENCOURAGING A SHIFT TO TRANSPORTATION MODES INVOLVING LOWER ENERGY CONSUMPTION AND EMISSION LEVELS

Increasing greenhouse gas concentrations in the atmosphere and air pollution are both linked to the burning of fossil fuels. A shift to transportation modes that use less energy and create fewer emissions is a key component of a sustainable transportation strategy.

5.1 Promoting Mass Transit

Based on the available evidence, this task force believes that for passenger movement, mass transit modes--including buses, ferries, railroads, subways, rapid rail vehicles, light rail vehicles, and trolleys--are more sustainable in general than the private automobile. Mass transit can reduce congestion, emissions and energy use and contribute to sound economic development. Per passenger, mass transit vehicles, on average, emit 50 percent less CO2 than an average automobile (see Table 12). They use 40-60 percent less energy per passenger mile (see Table).

To compete with private vehicles, urban transportation systems must offer the consumer safety, convenience, reliability, frequency, flexibility, and cost savings. Intercity transportation systems must offer reliability, speed, comfort and convenience.

Population densities of 30 to 40 people per hectare and higher support the development of urban mass transit systems. In Ontario, * percent of the population--lives or works in urban areas of the appropriate density--the majority in the Greater Toronto Area (GTA). In many rural and northern communities, however, mass forms of transportation are likely to be less viable than the automobile.

There exists in the Greater Toronto Area a network of railway rights-of-way which is not being used for passenger transit. The conversion of this network to passenger uses would provide an economical way to increase rapid transit routes and service.

Incentives to promote urban mass transit use include: transit pass systems, discounts for special groups, the establishment of priority lanes for buses, increased frequency of service, good intermodal connections, and tax bonuses for transit users.

The movement of people between cities in Ontario relies on buses, trains, and airplanes, as well as on the automobile, with distance determining the mode chosen. Air travel represents 15.5% of all passenger-kilometres travelled in Ontario. Rail represents 1%. Approximately 30% of all automobile travel is inter-city. If current trends continue air travel will increase to 19% and rail will decrease to 0.7%.

Rail is the only transportation mode, except for pipelines, that must assume all the costs related to the ownership and maintenance of its infrastructure. The full burden of these costs has a major impact on the financial viably of any railway investment. Outside North America most governments play a strong role in funding railway infrastructure.

Over 150 km, a high speed train becomes an attractive option in comparison with the automobile because of reduced travel time and lessened fatigue. For air travel, on routes of less than 700 km, the advantages of speed are more and more offset by higher costs and the difficulties of airport access.

Recommendations

5.1.1 That the Provincial government establish a Greater Toronto Area Transit Body to develop a long range strategic plan for urban transit development in the GTA, that includes:
- **major increases in capital and operating subsidies;**
- **integration of different mass transportation modes;**
- **efficient rapid transit systems supported by surface routes for major urban areas;**
- **establishment of innovative fare marketing programs to increase ridership and revenue**

5.1.2 That the Provincial government recommend that the Federal government revise Income Tax regulations to make transit passe tax deductible.

5.1.3 That the Provincial government and the Greater Toronto Area Transit Body undertake negotiations with CN, CP, GO and VIA rail to use the GTA rail network for rapid rail commuter service.

5.1.4 That the Provincial government negotiate for the development of a high speed rail system between Windsor and Quebec City.

5.2 Promoting Cycling

Bicycling is the most energy efficient mode of transport. For a ten-mile commute, a cyclist requires only 350 calories of renewable energy, a car driver uses up 18,600 calories of nonrenewable energy; a passenger on a bus requires 9,200 calories; and a train passenger uses 8,850 calories. Each person who cycles instead of taking the car avoids releasing at least 2.6 pounds of hydrocarbons, 20 pounds of carbon dioxide, and 1.6 pounds of NOx into the air per mile travelled (Gordon 1991). A spontaneous increase in commuter cycling (STATS) has persuaded some municipalities to increase support for bicycles.

Recommendation

5.2.1 That the Provincial government adopt a comprehensive bicycle strategy which includes requirements for on and off-road facilities, and integration with mass transit systems.

5.3 Promoting Walking

Walking is a viable transportation option for short trips. Safe, efficient pedestrian movement depends on well integrated land use and transportation planning. Strategies for encouraging walking include enhancing pedestrian access to employment, commercial, recreational, and transit facilities and transit by foot. Pedestrian facilities should be planned in conjunction with mass-transit.

5.4 Moving More Goods By Rail

The cleanest and most efficient ways to move freight over long distances are by ship and by rail. For the past 30 years, however, trucking has been steadily taking over the market share from rail because of the demand for "just-in-time" deliveries and small shipment sizes.

The choice of freight modes is governed largely by economics. If shippers had to pay the full costs--including the environmental costs--of transport, and if subsidies to roads were removed, rail would become more economically viable. Trucking is, and will continue to be, the most efficient mode of goods transport for relatively short trips and between many small, scattered destinations.

Intermodality--the combination of rail for long distance movement of bulk goods and road for short distance distribution of the same goods--would be the most sustainable option. Appendix III is an analysis of the implications on energy consumption and emissions of a modal shift from truck back to rail.

Recommendations:

5.4.1 That the federal and provincial governments promote and fund the development of intermodal terminals

5.4.2 That the provincial government assist industry in fostering intermodal cooperative ventures.

6. MANAGING WASTE FROM THE TRANSPORTATION SECTOR

The transportation sector contributes many substances to the waste stream, including: old vehicles and tires; used transportation vehicle fluids; waste from highway and road construction; salt runoff from deicing, which runs off into waterways; CFC's from auto air conditioning.

The Ministry of Transportation (MTO) has developed, cooperatively with the Ministry of the Environment, a comprehensive waste management program that meets provincial waste management legislation requirements. MTO efforts include the construction of highways without producing waste, and the use of tires as road building material. MTO has also made a commitment to use road salt judiciously, and research alternative deicing materials, the impact of highway runoff on receiving water quality, and better ways of handling this runoff.

It is estimated that roughly half of the total contribution a motor vehicle makes to global warming is from CFCs, used in vehicle air conditioning units. Vehicle manufacturers have made a commitment to eliminate the use of CFCs by 1996, and many require their dealers to recycle CFCs when servicing air conditioning.

One manufacturer, BMW, is developing a totally recyclable car by 2000.

Recommendations

6.1 That the Provincial government in cooperation with the vehicle manufacturers establish a project to identify means of achieving a totally recyclable car.

6.2 That the Federal government eliminate the use of CFCs in new vehicle car and light truck air conditioning units by 1996.

6.3 That the Federal and Provincial governments require the phase out of CFCs in the existing fleet of car and light duty truck air conditioners as substitutes become available.

6.4 That the Provincial government require that in the service of all vehicle air conditioners the CFCs be captured and recycled.

6.5 That the Federal and Provincial governments work with the U.S. government to require the phase out of CFCs in all other vehicle refrigeration and air conditioning, including heavy duty trucks, rail, airplanes and public transit vehicles, as soon as substitutes become available.

6.6 That the Provincial government in cooperation with vehicle and parts manufacturers, petroleum and chemical industries continue to study ways of reducing, reusing, recycling and recovering wastes from the manufacture and use of transportation related activities.

6.7 That the Provincial government in cooperation with vehicle and parts manufacturers, petroleum and chemical industries implement a province wide system to collect and recycle fluids and other wastes from the service of vehicles.

7. INFORMING DECISION-MAKERS

Sound informational polices can:

- raise the level of awareness of sustainable transportation practices;
- encourage a shift in lifestyle and behaviour towards transportation choices with the lowest environmental impact; and
- identify economic benefits and opportunities inherent in environmentally sustainable transportation policies.

One of the foundations of sound decision-making is accurate and up-to-date information. For the transportation sector, some of this information is not at present available; the rest can be obtained from a range of sources.

The Ontario Ministry of Transportation (MTO) has information on fleet composition. Until 1988, fleet usage information was monitored by Strategics Canada. Urban and intercity surveys, and traffic count programs, provide an alternative source of this information. Fuel consumption data for new vehicles is available from Transportation Canada. Statistics Canada has data on overall fuel usage rates until 1988. Limited information is available from an MOE spot check program.

Transportation associations and groups have begun to develop transportation codes of practice. The Ontario Trucking Association, for example, has adopted guidelines for an environmental code of practice. It also provides a waste management/ recycling service to its members, is encouraging members to reduce idling, and is investigating a joint tree planting initiative with the province.

MTO has developed a series of energy efficiency handbooks, instructional videos, and technical reports. This program is estimated to reach 80 percent of Ontario municipalities with a population of 5,000. MTO's Drive$ave/Truck$ave program provides fleet drivers and operators with information and instruction on improving fuel efficiency.

Recommendations:

7.1 **That the Provincial government establish a project for the development and maintenance of a common, comprehensive, up-to-date Provincial data/information base.**

7.2 **That the Provincial government undertake a public education campaign focusing on costs of automobile dependency and the benefits of environmentally sound alternatives including HOV programs, ridesharing, transit, cycling and walking.**

7.3 **That the provincial government undertake a program of driver training for the general public and fleet operators which includes information on driving techniques that reduce emissions and energy use.**

7.4 **That the Provincial government expand its formal education programs and materials through the establishment of an education policy within the Ministry of Transportation which educates teachers and students from kindergarten to OAC level about sustainable transportation.**

7.5 **That for all sustainable development decisions in the transportation sector, some form of public inventory or availability of information and rationale occur. Ongoing public education on the need for and benefits of sustainable development initiatives, would become essential in justifying unpopular initiatives.**

7.6 **That the provincial government develop and track a set of indicators for the transportation of both passengers and goods which includes:**

- **transportation energy per capita;**
- **transportation energy per vehicle;**
- **modal split;**
- **fuel share;**
- **energy efficiency and intensity by fuel share;**
- **emissions by fuel share;**
- **carbon intensity;**
- **total vehicle kilometres travelled by region;**
- **passengers per vehicle;**
- **share of GDP for transportation - auto/ steel/fuel; and**
- **air quality - ozone trends.**

8. ENSURING REGIONAL AND SOCIAL EQUITY

8.1 Measuring the Costs and Benefits

The task force recognizes that access to transportation services and facilities is essential to the social and economic well-being of every resident of Ontario.

Substantial changes to the provincial economy, and to the lifestyles of Ontario residents will likely be required to achieve sustainable development. Major changes promoted in this report include: increased use of alternative fuels; increased urban densities; incentives to transit and disincentives to the private automobile, at least in urban areas. These changes, for example, are likely to have an impact on the automotive sector, currently a major force in the provincial economy.

To ensure that such changes are accepted by individual Ontario residents, and that any trade-offs required are reasonable a sustainable transportation strategy must explicitly include information on social, economic and regional impacts.

The criteria for assisting some groups or regions more or less than others may include population size, tax base, economic growth, availability of natural resources, ability to be self-sufficient, etc.

Recommendations:

8.1.1 **That the Provincial Government develop and implement a system of full-cost accounting as a means to accurately measure the benefits and costs of all initiatives taken to promote sustainable development in the transportation sector.**

8.1.2 **That the provincial government determine the benefits and costs of these initiatives for different geographic regions of Ontario, including but not limited to Northern Ontario, and for special groups, including but not limited to Aboriginal peoples and people with special transportation needs.**

8.2 Developing Compensatory Mechanisms and Initiatives

The task force recognizes that a balance must be found between meeting environmental goals, meeting general demand for access to transportation, and responding to the demands and aspirations of groups with special transportation needs. The allocation of financial resources towards these needs is largely a political decision.

Recommendations

8.2.1 That the province review private and public sector transportation services and facilities to determine if and where additional resources should be allocated.

8.2.2 That where changes in the transportation sector will negatively affect society or its members, the province review ways to off-set negative impacts.

8.2.3 That the province identify ways--including subsidies and alternative services--to ensure that access to transportation is maintained, irrespective of an individual's ability to pay.

8.3 Promoting Sustainability for Northern Ontario:

Geographic isolation and greater distances in the north contribute to increased construction and operating costs for transportation systems, a different modal mix, and higher costs for goods and services.

Northern Ontario contains 46 percent (11,000 km) of the provincial highway system and 80 percent (30,000 km) of the province's access road system. This includes access roads provided by the Ministry of Transport (MOT), the Ministry of Northern Development and Mines (MNDM) and the Ministry of Natural Resources (MNR).

Although road is the primary transportation system in the north, many communities are not accessible by road during the winter. For these and more isolated communities in the far north, air is often the only long distance transportation mode. Local transportation needs may rely on snowmobiles, small boats, or walking. Marine transportation, which falls under federal jurisdiction, is relatively unimportant in the north because of the short shipping season. Although rail--another federal responsibility--has a long history of moving passengers and goods in the north, cutbacks to services in recent years have reduced its importance.

Residents of Northern Ontario tend to face higher costs for goods imported from the south and for services as well as for transportation. The economy of northern Ontario is based on the extraction and export of primary resources--notably trees and minerals. Efforts to add local value to these exports have, in general, not been successful. The barriers to local economic growth that must be overcome appear to be distance from potential markets, and "free-market" freight rate structures which encourage the bulk export of raw materials and the importation of manufactured goods.

The provincial government has supported the manufacture of transit vehicles in Thunder Bay, including a subsidy to municipal transit authorities that purchase the northern vehicles. Similar support to repair centres, a pilot training centre, the transport of bulk propane to northern communities, and the development of warehousing facilities, for example, could serve the long term interests of the transportation industry and provide northern Ontario with competitive advantages.

Recommendations:

8.3.1 That the Provincial government develop legislation requiring that provincial and municipal governments report on at least an annual basis, on transportation sector decisions that affect northern Ontario. These decisions should include a rationale based on full cost accounting.

8.3.2 That the Provincial government, in conjunction with northern transportation stakeholders, undertake a comprehensive and ongoing review of the transportation needs and potential of Northern Ontario.

8.3.3 That the Provincial government develop a strategy for the delivery of co-ordinated, integrated transportation services in Northern Ontario that includes:

- **the requirement that all government actions consider the impacts on Northern Ontario, and the public release of these considerations;**
- **alternative modes of transportation for goods, including rail and barge;**
- **modifications to infrastructure which permit increased operating speeds and haulage capacity;**
- **procedures and policies to encourage that trucks and other goods carriers coming into northern Ontario carry "full loads".**

8.3.4 That the Provincial Government investigate ways of increasing government support to transportation-related industries and initiatives in Northern Ontario.

8.3.5 That the Provincial government investigate ways of adding local value to resource extraction activities, possibly through local manufacturing initiatives.

8.4 Promoting Sustainability for Aboriginal Communities

The Province of Ontario is currently working out a new formal relationship with its Aboriginal peoples and communities. Any sustainable transportation strategy developed for the province will likely be worked out in tandem with the over-all strategy for aboriginal self-government, and recommendations made here modified as this strategy evolves.

The transfer of responsibilities and authorities from the provincial government to aboriginal peoples is an essential part of the process. In the transportation sector, this may give aboriginal peoples a new degree of control over services, facilities and infrastructure which provide access to aboriginal communities and traditional areas. Potential areas for future partnerships include the planning, design, construction, operation and maintenance of transportation infrastructure and systems.

In order for Aboriginal people and communities to enjoy the fullest degree of participation and involvement in provincial transportation proposals, they will need to have sufficient information and procedural and technical advice and assistance available. Part of the current thrust of the government's new relationship with Aboriginal communities and peoples is to provide such assistance in all areas as is needed to enable their full participation.

Recommendations:

8.4.1 That the Province review and amend existing legislation (e.g. Public Safety and Highway Improvement Act, ss 64, 75, etc.) to remove references to "delegated" authority and to amend them to reflect the "equivalent to government" relationship which now exists.

8.4.2 That the province amend existing legislation to authorize MTO and other provincial transportation authorities/agencies to establish separate subsidy and other financial support mechanisms and procedures for Aboriginal transportation matters.

8.4.3 That the province review existing transportation services and functions provided by the provincial government (through MTO, MNR, MNDM, etc.) to assess the potential for entering into partnerships with individual First Nations.

8.4.4 That the province review existing provincial training programs and establish new construction and maintenance programs to promote training opportunities for Aboriginal people;

8.4.5 That the province review its transportation network to determine the options that exist for Aboriginal initiatives to fill "empty" components, or add to existing transportation services and functions, with provincial support if necessary.

8.4.6 That the province attempt to develop partnerships with the federal government to ensure that Aboriginal rights and issues are fully considered where the province does not have full jurisdiction to act on its own in transportation matters.

8.4.7 That the Province assess the need to review and review its means and criteria for providing funding or other assistance to Aboriginal communities on transportation-related undertakings and initiatives.

8.4.8 That the Province review and asses the necessary and appropriate efforts to ensure that notifications and participation processes are compatible with Aboriginal government structures and aspirations.

8.4.9 That the Province develop a process to ensure that serious consideration of transportation proposals and initiatives from Aboriginal communities occurs.

8.5 Promoting Sustainability for Seniors and the Handicapped

In their 1987 report, the Ontario Advisory Councils on Senior Citizens and on the Physically Handicapped concluded that "the freedom to move is life itself". "No matter where you live in Ontario" says the report, "in northern communities, on Reserves or in rural or urban communities - transportation is the essential link between home, work, medical facilities, religious centres, shopping, volunteer and social activities. Without transportation many are denied the opportunity to be independent." (Freedom to Move is Life Itself: A Report on Transportation in Ontario).

Ontario currently provides or supports a number of transportation services and facilities for disabled persons, including: subsidies to municipal transportation systems for accessible vehicles and facilities; parking stickers; support to private service taxi and bus services; and demonstration projects. Over 120 municipalities in the province provide special transportation services for disabled and elderly people. Provincial government contributions towards the capital and operating costs of these services are the highest, per capita, in North America. In 1990, the province made a commitment to achieve the long term goal of fully accessible public transportation in a fiscally responsible manner.

Despite this support, there is a province-wide shortage of accessible transportation at the local, regional and inter-city level, especially in Northern Ontario. Furthermore, existing accessible transportation services and programs may not be provided in as efficient as manner as possible.

Recommendations:

8.5.1 That the Provincial Government ensure that any sustainable transportation strategy developed for the province meet the demands for accessible transportation.

8.5.2 That the Provincial Government develop additional programs and financial support mechanisms to meet demands for accessible transportation, through government/public sector, private sector, and public/private sector partnerships.

8.5.3 That the Provincial Government incorporate mechanisms in full-cost accounting to "capture" impacts and needs for accessible transportation.

8.5.4 That the Provincial government develop procedures for ensuring coordination and communication between the various jurisdictions and providers of accessible transportation services.

APPENDIX II: THE DATA BASE

The following data was provided to the Task Force by VHB Research & Consulting Inc. It was prepared fro the ontario Ministries of Energy, Transportation and Environment as part of a report entitled *Reduction of Energy Use and Emissions in Ontario's Transportation Sector*. Baseline energy estimates are based on model output from the Ontario Ministry of Energy's Energy Demand Model. This model provides highly disaggregated information on transportation demand, vehicle efficiencies, and fuel type. Baseline emissions estimates were derived using standard factors from the technical literature.

Transportation accounts directly for approximately 6% of Ontario's Gross Provincial Product. Its indirect contribution has been estimated at between 15-2-%. On average, transportation tends to account for about 10% of the cost of a typical product or service.

Households, businesses and government typically spend 10-15% of their budgets on transportation services and equipment. In addition, the public investment in transportation facilitates, services and administration accounts for approximately 6% of the Provincial budget and about 10-15% of the typical municipal budget.

Transportation directly employs 11% of Ontario's work force. See Table 7. It also indirectly employs many other workers including, people who produce and deliver goods, public sector staff overseeing transportation policy, police, fire, ambulance services, insurance companies, etc.

Table 1

The transportation sector accounts for just under one quarter of total energy use in Ontario. This is not expected to change significantly over the next fifteen years:

Energy use in Ontario (PJ/a)

	1988		2005		Growth (%)
	PJ/a	%	PJ/a	%	
Industrial	1138	44	1743	49	53%
Transportation	619	24	804	23	30%
Residential	485	19	554	16	14%
Commercial	334	13	454	13	36%
Total	2576	100	3555	100	38%

Source: MENY, 1990:54

Table 2

Transportation accounts for a very large component of the use of refined petroleum products.

Energy use and refined petroleum products by section (1989)

	Total energy		Refined petroleum products	
	PJ/a	%	PJ/a	%
Transportation*	664	27	605	72
Industrial	832	34	80	10
Residential	496	20	60	7
Comm. & Instit.	348	14	56	7
Public Admin.	38	2	13	2
Agriculture	43	2	22	3
Total	2,419	100	837	100

Source: Statistics Canada, 1990:81,85.

*Differences between this and the previous table reflect differences between how the Ontario Ministry of Energy and Statistics Canada define sectors, and the way non-energy products are treated.

Table 3

Key Economic Variables

	1988	2005	Growth (%)
Population (millions)	9.4	11.4	21%
Total real GDP (1971 M$)	60,196	99,389	65%
Automobile registration (millions)	4.6	6.5	41%
Households (millions)	3.5	4.8	37%

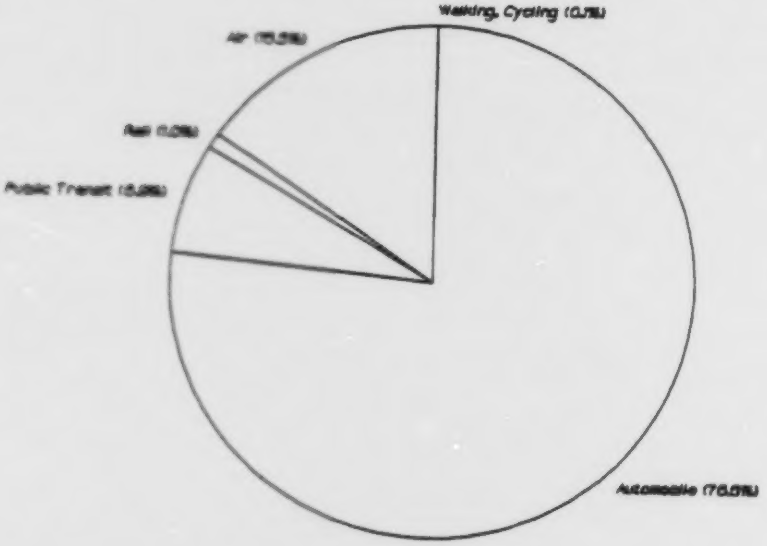
Source: Ontario Ministry of Energy 1990

Table 4

How People Travel Today in Ontario
1990

Mode	Millions of Vehicle-Kilometres	Millions of Passenger-Kilometres
Walking, Cycling	200	200
Automobile	75,590	140,066
Public Transit		
Inter-City Bus	152	3,502
Urban and GO Transit	457	9,135
Rail (VIA and ONTC)	12	1,810
Air	298	28,313
Totals	76,709	183,026

Passenger-Kilometres



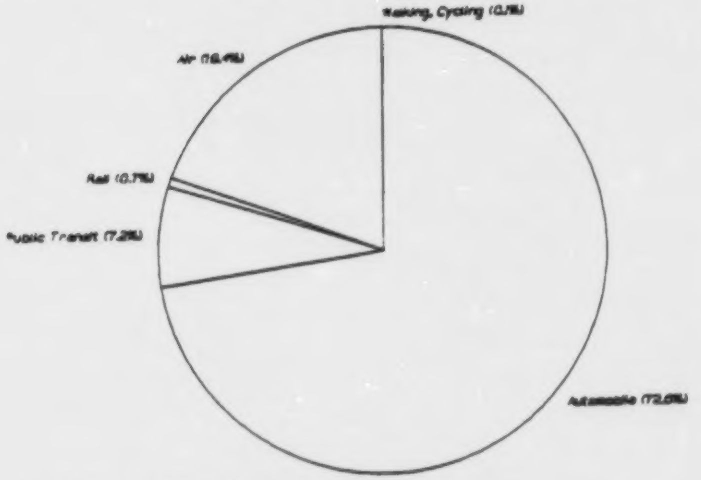
Source: Adapted from Ministries of Energy/Transportation/Environment, 1991.
"Reducing Energy and Emissions in Ontario's Transportation Sector (Draft)"

Table 5

How People Will Travel Tomorrow in Ontario
(If Current Trends Continue)
2005

Mode	Millions of Vehicle-Kilometres	Millions of Passenger-Kilometres
Walking, Cycling	250	250
Automobile	103,350	191,508
Public Transit		
Inter-City Bus	230	5,297
Urban and GO Transit	691	13,820
Rail (VIA and ONTC)	11	1,746
Air	539	51,202
Totals	105,071	263,823

Passenger-Kilometres



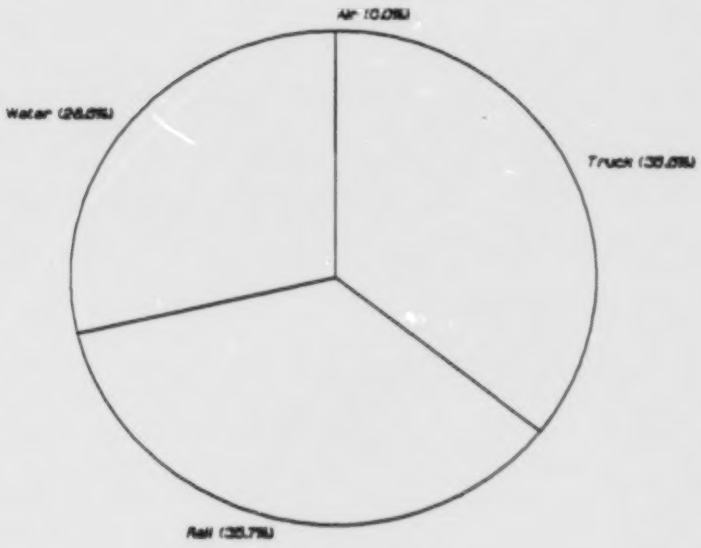
Source: Adapated from Ministries of Energy/Transportation/Environment, 1991.
"Reducing Energy and Emissions in Ontario's Transportation Sector (Draft)"

Table 6

How Freight Moves Today in Ontario
1990

Mode	Millions of Vehicle-Kilometres	Millions of Tonne-Kilometres
Truck	20,889	32,303
Rail	16	32,407
Water	-	25,979
Air	18	21
Totals	20,923	90,710

Tonne-Kilometres



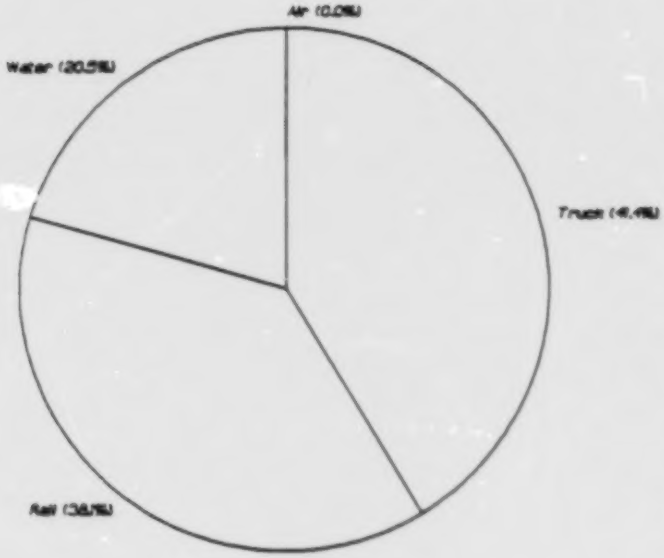
Sources: Adapted from Ministries of Energy/Transportation/Environment, 1991.
"Reducing Energy and Emissions in Ontario's Transportation Sector (Draft)"
Statistics Canada 1989. 53-222: Trucking in Canada, 52-216 Rail in Canada
51-002: Air Carrier Operations in Canada, 54-205: Shipping in Canada

Table 7

How Freight Will Move Tomorrow in Ontario
(If Current Trends Continue)
2005

Mode	Millions of Vehicle-Kilometres	Millions of Tonne-Kilometres
Truck	32,978	57,712
Rail	26	53,202
Water	-	28,589
Air	30	35
Totals	33,034	139,538

Tonne-Kilometres



Source: Adapted from Ministries of Energy/Transportation/Environment, 1991.
Reducing Energy and Emissions in Ontario's Transportation Sector (Draft)"

Roads

Ontario currently maintains about 21,500 kilometres of highways. Much of the current emphasis has shifted away from constructing new roads to maintenance of the existing system as more bridges and highways reach the end of their economic lives.

Trucking

Ontario trucking industry is divided into the private and for-hire sectors, Private trucking consists of companies who use their own fleets and dedicated drives to mover their own goods. For-hire trucking refers to carriers who are contracted to move goods for others. In total, trucking directly employs approximately 228,000 workers in Ontario or five percent of the provincial labour force. Trucks currently carry about 70 percent of Ontario's exports to the United States and about 75 percent of the province's imports from the United States.

Since the early 1980s, manufacturers, retailers and wholesalers have significantly reduced the number of days they hold inventory. Parts inventory for the automotive sector is only held in supply for four to eight hours. Consequently, Ontario industries utilizing "just in time" inventories are greatly dependent on the truck transportation industry.

The for-hire trucking industry is highly competitive, both within itself and with the rail and marine modes. The largest issue facing Ontario truckers in their ability to compete with U.S. firms which they feel have unfair advantages in terms of more relaxed operating regulations and lower costs of doing business.

Rail

There are 12,500 kilometres of rail lines in Ontario. Ontario goods rail industry employs about 17,000 people and is dominated by the publicly-owned Canadian National Railways (CN Rail) and the privately owned Canadian Pacific Railways (CP Rail) which together account for approximately 80% of rail goods movement in Ontario. The remainder is carried by north-south, resource-based lines such as those operated by the provincially-owned Ontario Northland Transportation Commission (ONTC) and the Algoma Central Railway.

Long distance, high value goods movement by rail has been lost to fierce truck price competition, leaving existing rail infrastructure underutilized. Rail operators and their workers are responding with new initiatives in service and investment.

The passenger rail industry is comprised of federally-owned VIA Rail Inc. and the ONTC. Service on these lines has been cut in recent years. The two year study exploring the feasibility of a high speed passenger rail service in the Ontario/Quebec corridor found that a modern, highly visible high speed passenger train service between Quebec City and Windsor would improve passenger travel, business and tourism and reduce congestion. A separate Ontario government operation, "GO" provides commuter rail service to the Toronto-centred region, on

CN and CP tracks.

Marine

The Ontario marine industry employs about 4,000 people. Its business is built around a small number of high-volume, low-value, time-intensive bulk goods such as wheat, iron-ore, coal and limestone. The industry has been in decline for twenty years with a decline of 50% in cargo traffic through the Welland Canal in the 1980's.

Air

The airline industry employs about 25,000 people to service Ontario's 100 airports. It is owned by the private sector, except for NorOntario which is operated by the ONTC. The domestic industry was officially deregulated in 1988. It is currently dominated by Air Canada and Canadian Airlines International Limited. The greatest issue for airline industry is maintaining market share in an "open skies" policy, or variations thereof, between the U.S. and Canada.

Bus

The Ontario intercity bus industry consists of approximately 100 individual companies employing about 7,000 people. The top three companies (Greyhound, Voyageur and Grey Coach) command approximately one quarter of the market. All carriers are privately owned, with the exception of the ONTC bus service. The industry is tightly regulated with operators granted monopolies on routes.

Urban Transit

The Ontario urban transit industry employs some 16,000 people in about 60 transit systems throughout the Province. With the exception of GO Transit, which is run by the Province, all systems are operated by the municipalities themselves (sometimes through private contractors or public utilities). On average, Ontario transit systems recover about half to two-thirds of their operating costs from the farebox with the remaining shortfall being split between the Province and each municipality. Currently, the Province contributes three quarters of the cost of capital expenses, with the remaining quarter coming from the municipality.

Greater Toronto Area

The Greater Toronto Area (GTA) is made up of the Municipality of Metropolitan Toronto and the Regional Municipalities of Halton, Peel, York and Durham. Within the five regions there are a total of thirty area municipalities.

The road system is organized in three levels:

- a provincial network of major freeways and inter-city highways built and operated by the Ministry of Transportation of Ontario (MTO)

- systems of major arterial roads owned and operated by each of the five regions
- roads owned and operated by the area municipalities which include arterial roads, collectors and local roads

There are 16 public transit systems operating in the GTA:

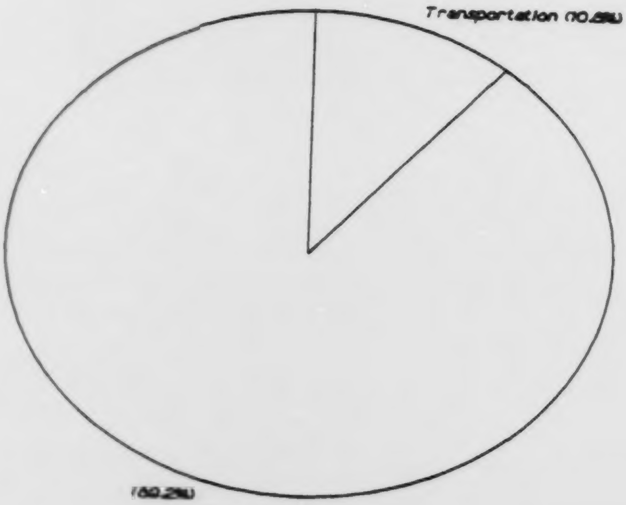
- GO Transit which is provincially funded and operates inter-regional rail and bus services
- TTC which operates public transit services on behalf of Metropolitan Toronto with some extensions into adjacent municipalities
- a total of 14 transit systems operated by area municipalities in other regions.

Table 8

Transportation Employment in Ontario
1990

Industry	Employment
Vehicle Parts, Accessories and Equipment Manufacturing	143,300
Carriers, Maintenance	162,700
Road Construction	10,600
Motor Vehicle and Accessory Wholesalers	24,000
Motor Vehicle and Accessory Retailers	107,800
Total Transporation Workforce	448,400
Total Ontario Workforce	4,143,500

Ontario Workforce
Employed in Transportation



Source: Statistics Canada 1990. 72-002 Employment, Earnings and Hours - Jan.

Table 9

US Passenger and Domestic Intercity-Freight Energy Intensities (1987)

Transport Mode	Energy Intensity	
	(Btu/vehicle-mi)	(Btu/pass-mi)
PASSENGER		
Automobile[a]	6,530	3,841
single occupancy	6,530	6,530
carpool	6,530	2,230
Motorcycle	2,496	2,269
Personal Truck/Van	9,048	4,762
single occupancy	9,048	9,408
vanpool[b]	9,048	1,094
Bus		
Transit	38,557	3,761
Intercity	20,176[c]	939
Air[d]	220,721	4,988
Rail		
Intercity[e]	52,107	2,537
Transit[f]	80,550	3,534
Commuter	113,228	3,138
Bicycle	200	200
Walking	300	300
FREIGHT	(Btu/ton-mile)	
Truck	1,898	
Water vessel	402	
Pipelines[g]	270-2,765	
Train	443	
Aircraft	n/a	

Notes:

a. Average of all autos on-road; 1.7 passengers/vehicle; carpool assumes 3 passengers/vehicle

b. Assumes average occupancy of 9 passengers per vehicle.

c. 1986 data.

d. Commercial airlines and general aviation only.

e. Amtrak only.

f. Light rail and rapid (heavy) rail.

g. Very wide range of pipeline energy intensity: 270 Btu/ton-mile for crude oil to 2,765 Btu/ton-mile for coal slurry.

Sources: Davis (ORNL) 1989; Komanoff 1990.

EXISTING EMISSIONS

The transportation sector is a major source of air pollutants. Emissions from the transportation sector contribute to a large number of environmental issues, including: global warming, urban smog, adverse effects on human and animal health, terrestrial ecosystems, and aquatic ecosystems; damage to materials; and localized and urban impaired visibility. The emissions from transportation sources of most concern are: volatile organic compounds (VOCs), oxides of nitrogen (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), diesel particulate, and oxides of sulphur (SO_x). Other more toxic compounds may be of concern in particular circumstances.

Environment Canada and Transport Canada (1989) have recently published national estimates of the portion of total emissions of each pollutant that are accounted for by transportation sources. Baseline and forecast emissions inventory data for NO_x and VOCs, disaggregated by province, were also recently published by the Federal\Provincial Long Range Transport of Air Pollutants Steering Committee (1990). The Ministry of the Environment periodically prepares emissions inventories for Ontario that include the portion of all emissions from transportation sources.

For each of the main pollutants from transportation sources, the relative contribution of transportation sources to total emissions and their adverse effects are summarized below. The summaries are drawn largely from the sources mentioned in the two previous paragraphs.

Volatile organic compounds (VOCs)

VOCs are the volatile portion of unburned hydrocarbons (fuel) that are emitted from vehicle engines. The main sources of unburned hydrocarbons are exhaust gases and evaporative losses from engines and during re-fuelling.

Gasoline-fuelled vehicles account for more that 85 per cent of VOCs from transportation sources. The transportation sector as a whole accounts for about 42 per cent of VOC emissions from all anthropogenic sources.

Some volatile organic compounds are irritants and so may effect exposed skin or other tissues. At high concentrations, these materials effect the brain and nervous system. At lower concentrations, overt effects are not commonly seen for most VOC. However, some VOC are considered toxic at low concentrations and have been associated with a variety of toxic effects, ranging from reproductive failure to cancer.

In addition, some types of VOC, often described as reactive organics (ROG), participate in the generation of ground-level ozone. When VOCs and NO_x interact in the atmosphere while exposed to sunlight they convert normal oxygen (O_2) to ozone (O_3). The major adverse effects of ozone are increased incidence of respiratory symptoms and aggravation of respiratory disease, damage to natural flora and agriculture crops.

Oxides of nitrogen (NO_x)

NO_x is a by-product of combustion, and is emitted in the exhaust gases from internal combustion engines.

Diesel-fuelled road vehicles and air, marine, and rail sources account for about 55 and 15 per cent, respectively, of NO_x emissions from transportation sources. The transportation sector accounts for about 63 per cent of NO_x emissions from all sources.

As well as being a precursor of ozone, elevated ambient concentrations of NO_x are responsible for a number of other adverse effects, including: irritation that may lead to discomfort or damage to exposed moist tissues including the lungs, fading of some fabrics, contribution of nitrate and nitric acid to acidic precipitation, and contribution to the formation of smog. Nitrous oxide accounts for about four per cent of the climate effect of 1990 anthropogenic emissions (IPCC, 1990)

Carbon monoxide (CO)

CO is also a by-product of combustion.

Gasoline-fuelled road vehicles account for about 94 per cent of CO emissions from transportation sources. Diesel-fuelled trucks and air, marine and rail sources account for the remaining CO emissions from transportation sources.

Elevated ambient concentrations of CO result in a number of adverse health effects including: increased risk of heart attacks, aggravation of symptoms of cardiovascular disease, decreased work capacity, impaired vigilance and abnormal fetal development.

Carbon Dioxide (CO_2)

CO_2 is another by-product of combustion of carbon-based fuels.

CO_2 emissions from transport vehicles account for between 25 and 30 per cent of total CO_2 emissions.

CO_2 is the main greenhouse gas, accounting for more than 60 per cent of the cumulative climate effect of anthropogenic emissions (IPCC, 1990; Allen, 1990). If atmospheric concentrations are to be stabilized at current levels, a reduction in the global level of CO_2 emissions of greater than 60 per cent is required (IPCC, 1990).

Diesel Particulate

Diesel particulates are a component of diesel exhaust.

Transportation sources account for almost two-thirds of total diesel fuel oil consumption in Ontario (Statistics Canada, 1989), and could be expected to account for a comparable proportion of diesel particulate emissions.

Diesel particulate consists of approximately 75 per cent carbon (soot) and 25 per cent polycyclic aromatic hydrocarbons (PAHs). Soot is a major cause of smog. A number of PAHs found in diesel particulate are known and suspected carcinogens and mutagens.

Sulphur Oxides (SO_2)

While transportation sources account for only 2 to 3 per cent of all SO_2 emissions[1], they are included here for the sake of completeness. SO_2 emissions are the primary cause of acidic precipitation.

DETERMINANTS OF EMISSIONS

The emissions factors for sulphur dioxide (SO_2), oxides of nitrogen (NO_x), particulates, carbon monoxide (CO), and volatile organic compounds (VOC) were provided by the Air Resources Branch. The carbon dioxide (CO_2) emissions factors are from Environment Canada (1990).

SO_2 emissions from the transportation sector are determined largely by the sulphur content of the fuel. SO_2 emissions factors for road vehicles are based on an average sulphur content in gasoline of 0.03 percent by weight and in diesel of 0.02 percent by weight.

Most of the particulates that are emitted from transportation sources come from the tires and brake linings of road vehicles. Particulates are also emitted in the exhaust from diesel engines.

The NO_x, CO, VOC emissions factors depend on the type of emissions control equipment on the fleet, the temperature (season), and whether the vehicle-kilometres travelled (VkmT) are accumulated during cold start and warm-up of the engine (primarily urban driving) or when the engine is warmed up (primarily highway driving). Emissions factors were calculated using the MOBILE4C computer program. They are average annual values that take into account the emissions control equipment of the Ontario fleet, seasonal temperature, and the split between urban and highway driving. Emissions factors are generally lower in the summer than in the winter and lower during highway driving than during urban driving.

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[1] The main sources of SO_2 are coal-fired power plants and non-ferrous ore smelters.

Carbon dioxide emissions factors depend on the carbon content of the fuel. CO_2 emissions factors are based on the assumption that all of the carbon emitted when the fuels are burned combines with oxygen in the atmosphere to become CO_2.

PROJECTIONS OF EMISSIONS

Emissions forecasts for 1990, 1995, 2000, and 2005 were estimated from projected fuel use (CO_2 and SO_x), and VkmT (VOCs, NO_x, CO and particulate). The baseline emission projections account for changes in the emissions factors for each forecast year which reflect new emissions standards and fleet turnover.

The emissions factors used in the forecasts are as follows:

SO_2 emissions factors are held constant through to 2005 at the 1985 levels. SO_2 emissions factors are largely determined by the sulphur content on the fuel used. Environment Canada published its intention to regulate the sulphur content in diesel fuel under the Environmental Protection Act in the June 30, 1990 *Canada Gazette, Part I.* The regulation under consideration will limit the sulphur content of diesel fuel to 0.05 percent by weight, effective October 1, 1993. If the regulation is promulgated, the sulphur content of diesel fuel will fall substantially from its current average of 0.22 percent by weight, and SO_2 emissions factors for diesel engines will drop sharply. As a result, SO_2 emissions from transportation sources would decline by 40 to 45 percent from the baseline 2005 projection. Further reductions in SO_2 emissions will be achieved by measures that reduce the amount of fuel that is consumed.

Particulate emissions factors are also kept constant over the forecast horizon at 1985 levels. Few changes are anticipated in the amounts of particulate emitted as a result of tire and brake lining wear. However, any reduction in the sulphur content of diesel fuel will result in a reduction in particulate emissions from diesel engines as well. In addition, increasingly stringent particulate standards for diesel-powered road vehicles are scheduled to come into effect between 1990 and 1994. The combination of limits on the sulphur content of diesel and stringent diesel particulate standards will greatly reduce any environmental damage that is caused by diesel particulate. Further reductions in particulates will be achieved by measures that result in reductions in the number of VkmT by road vehicles or the amount of fuel consumed.

NO_x, CO and VOC emissions factors used in the forecasts for road vehicles were obtained from Environment Canada. They are the same emissions factors as those used for the forecasts in the *Federal\Provincial Management Plan for Nitrogen Oxides (NO_x) and Volatile Organic Compounds (VOCs)* (March, 1990) The emissions factors show substantial declines between 1985 and 2005. These declines are the results of more stringent emissions standards that came into effect in September, 1987 (i.e., for the 1988 model year) for passenger cars and light trucks and in 1990 for heavy duty trucks and buses. As more of the motor vehicles that were manufactured prior to the implementation dates of the new standards are retired from the active fleet, the fleet average emissions factors will decline. Further reductions in emissions of NO_x, CO and VOCs from road vehicles will be achieved by measures that reduce the number of VkmT and by more stringent emissions standards.

The NO_x, CO, VOCs emissions factors used in the forecasts for railroads, aircraft, marine sectors are kept constant to 2005 at the 1985 levels.

CO_2 emissions factors used in the forecasts are held constant for all fuel types. Since CO_2 emissions factors are based on the carbon content of fuels, the only measures that are effective in reducing CO_2 emissions are those that result in a reduction in the amount of carbon-based fuels that are consumed.

The baseline forecasts do not include the effects of measures that are under consideration for implementation before 2005 but for which effective dates and the details have not been announced. Some of the measures excluded from the baseline include:

- more stringent emissions standards which are being considered by Transport Canada for the mid-1990's
- fuel economy standards like, for example, U.S. Corporate Average Fuel Economy standards
- motor vehicle inspection and maintenance programs.

Emissions production is usually calculated from the energy demand equation (1) above. All of the emissions of concern to this study, emitted from transportation sources, are directly proportional to either *Energy Consumption* or *Amount of Activity:*

*Emissions Production = Emissions/Unit of Energy * Amount of Energy*

*Emissions Production = Emissions/Unit of Activity * Amount of Activity*

The baseline emissions forecasts are summarized in Table 10.

Table 10

Baseline emissions quantities forecast for Ontario's transportation sector (kt/a)

Emission Type	Year				
	1988	1990	1995	2000	2005
SO_2	26	27	31	37	42
NO_x	306	243	225	193	207
Particulate	38	41	46	52	57
CO	1,896	1,344	1,218	1,019	1,079
VOC	241	190	173	138	145
CO_2	42,281	44,034	48,283	51,208	54,712

Comparison of emission projections with other estimates

As a result of using lower base quantities during 1985 for diesel-powered road vehicles than those used by the MOE Air Resrouces Branch, the emissions quantities for the 1985 baseline are lower than the Air Resoures Bramnch's. The baseline emissions forecasts are also lower than the Environment Canada forecasts in the *Federal/Provincial Management Plan for Nitrogen Oxides (NO_x) and Volatile Organic Compounds (VOCs)* (March, 1990). Environment Canada used even higher base quantities during 1985 for diesel-powered road vehicles than did the Air Resources Branch. Environment Canada's growth factors were also substantially higher than those used by the National Energy Board, or the MENY model.

The quantity of SO_2 emissions are shown as growing steadily. However, as described above, a relatively simple "technical fix"–limites on the sulphur content of diesel fuel–is under consideration and, if implemented, will result in a substantial reduction in SO_2 emissions. In any case transportation sources account for only about two to three percent of all SO_2 emissions.

Particulate emissions are also shown as increasing to 2005. However, measures to control the fraction of total particulates which are considered the greatest threat to the environment, those emitted by diesel-powered road vehicles, have been implemented. Neither SO_2 nor particulate emissions from transportation sources are expected to present serious problems in 2005.

NO_x, Co and VOC emissions are all shown as decreasing steadily until 2000 and then starting to increase by 2005. By the year 2000 virtually all of the motor vehicles manufactured prior to the effective dates of the latest emissions standards will have been retired from the active fleet and the fleet average emissions factors will have levelled off. Fuel consumption and its direct correlate, CO_2 emissions, are expected to grow steadily under the assumptions of the baseline forecasts. In the absence of more stringent emissions standards total NO_x, CO and VOC emissions will start to increase after 2000 withy any increase in VkmT. Wth the exception of more stringent emissions standards, allo of the measures aimed at reducing emissions will also result in less fuel consumption and *vice versa*. More stringent emission standards will be included as a measure in all of the strategies,s the focus of the strategies will be on measures that reduce fuel consumption and CO_2 emissions. This approach will ensure that any straegies that are formulated to meet fuel consumption and CO_2 reduction goals will also result in maximum reductions for other emissions.

Table 11

Estimates of annual CO_2 emmissions production in Ontario

Sector/Mode	CO_2 Emissions Production (kt/a)				
	1988	1990	1995	2000	2005
Auto	20,058	21,265	23,313	23,702	24,909
Truck	10,684	10,962	11,774	13,112	13,852
Airplane	4,244	4,348	5,006	5,394	6,070
Light truck	3,182	3,254	3,520	3,805	4,130
Rail	1,616	1,626	1,800	1,991	2,166
Marine	1,297	1,328	1,459	1,636	1,828
Other[a]	587	618	705	808	928
Bus	545	562	630	683	748
Streetcar/Subway	0	0	0	0	0
GO train	68	70	75	78	82
Total	42,281	44,034	48,283	51,208	54,712

[a] "Other" includes motorcycles, school buses and recreational vehicles

Table 12

Comparison of Emissions Between Various Passenger-Transport Modes*

Transport Mode	CO_2 (lb/pass-mi)	NMHC[1]	CO	NO_x	TSP	SO_2[2]
TRUCK (gasoline):						
-Single Occupancy	1.55	3.20	27.46	2.05	0.01	0.23
-Average Occupancy	0.81	1.68	14.45	1.08	0.01	0.12
CAR:						
-Single Occupancy	1.12	2.57	20.36	1.61	0.04	0.14
-Average Occupancy	0.68	1.51	11.98	0.95	0.03	0.08
VEHICLE RIDESHARE:						
-3 person carpool	0.37	0.86	6.79	0.54	0.01	0.05
-4 person carpool	0.28	0.64	5.09	0.40	0.01	0.03
-9 person carpool	0.17	0.36	3.05	0.23	<0.01	0.03
BUS (diesel):						
-Transit	0.39	0.25	1.21	1.82	0.17	n/a
RAIL:						
-Amtrak/intercity						
diesel	0.43	0.12	0.6	0.9	0.08	0.51
electric	0.26	neg	0.05	1.1	0.08	2.07
-Commuter (diesel)	0.53	1.04	1.44	4.10	0.28	0.63
-Transit (electric)	0.37	meg	0.06	1.48	0.11	2.89
AIRCRAFT[3]	0.57	0.05	0.52	1.08	n/a	0.08
BICYCLE	0	0	0	0	0	0
WALK	0	0	0	0	0	0

Notes:

- Emission factors (convert from emissions in vehicle-miles to emissions in passenger-miles using occupancy factors from table 2):

Diesel: 1.68 x 10-4lb CO_2/Btu
Gasoline: 1.71 x 10-4lb CO_2/Btu
Jet fuel: 1.66 x 10-4lb CO_2/Btu

Electricity: 1.04 x 10-4lb CO_2/Btu-equivalent; neg. NMHC; 0.04lb CO/MBtu; 0.92 lb NO_x/ MBtu; 1.8lb SO_2/MBtu; 0.067lb TSP/MBtu (Average 1987 power plant emissions in U.S.).

Heavy-duty diesel engines: 2.51g NMHC/veh-mi; 12.3g CO/veh-mi; 18.5g NO_x/veh-mi; 1.7g TSP/veh-mi.
Single passenger auto: 2.57g NMHC/veh-mi; 20.36g CO/veh-mi; 1.61g NO_x/veh-mi; 0.04g TSP/veh-mi.
Single passenger light truck: 3.2g NMHC/veh-mi; 27.5g CO/veh-mi; 2.1g NO_x/veh-mi; 0.01 TSP/veh-mi.

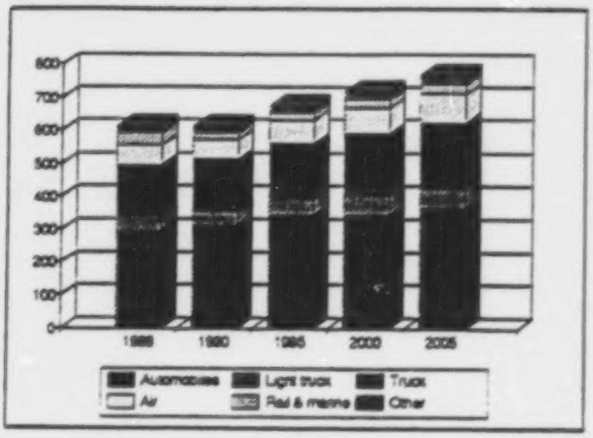
1. NMHC–Nonmethane hydrocarbons or reactive organic compounds, 9RVP.
2. SO_2 emissions calculated based on 0.03 weight percent sulfur in gasoline fuel.
3. Assumes a PW4050-powered 767-200 flying 288 statute miles (250 nautical miles) seating 65% of its 240-passenger capacity. (Note: emissions per passenger-mile change proportionately with passenger occupancy–e.g., if this aircraft was only 25% full, emission factors would increase by a factor of 2.6)

Sources: Davis (ORNL) 1989; EIA, May 1989; author's calculations; EPA Mobile4 model and personal communications with Lois Platte (EPA Ann Arbor Laboratory); personal communications with Walt Stevenson (EPA Research Triangle Park, NC); personal communications with Frane Pane, United Technologies-Pratt and Whitney, East Hartord, CT.

Energy use and emissions

Table 13

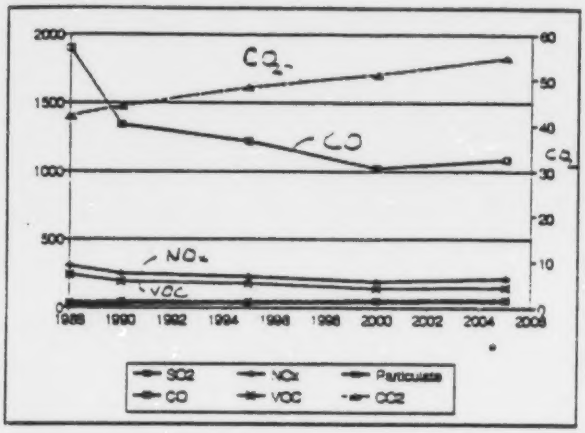
The figure and table show energy use by mode (PJ/a)



	1988	1990	1995	2000	2005
Auto	295	313	343	348	366
Light truck	47	47	52	56	61
Truck	155	155	170	189	200
Airplane	60	60	70	76	85
Rail	23	23	25	28	31
Marine	17	17	20	22	25
Other	9	9	10	12	14
Bus	8	8	9	10	11
Streetcar & subway	1	1	1	2	2
GO-train	1	1	1	1	1
	616	634	701	744	796

Source: VHB 1991

Table 14

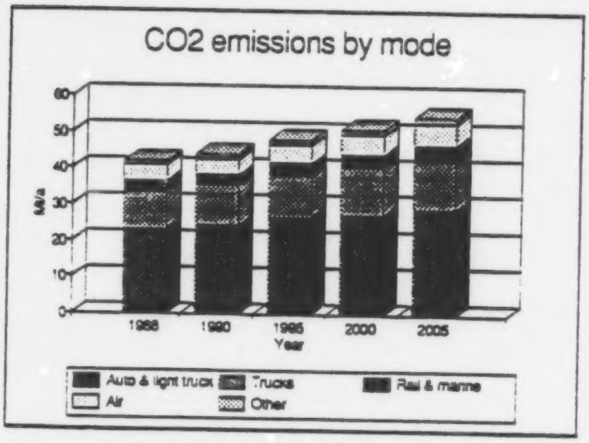


Emissions by contaminant

	1988	1990	1995	2000	2005
SO_2 kt/a	26	27	31	37	42
NO_x kt/a	306	243	225	193	207
Particulate kt/a	38	41	46	52	57
CO kt/a	1896	1344	[illegible]	1019	1079
VOC kt/a	241	190	[illegible]	138	145
CO_2 Mt/a	42	44	48	51	55

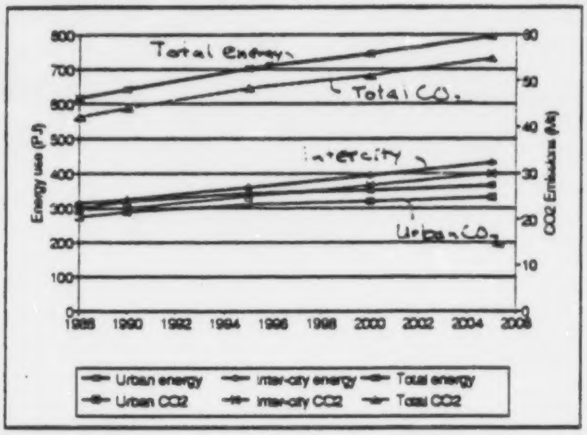
Mt — million tonnes
kt — thousand tonnes

Table 15



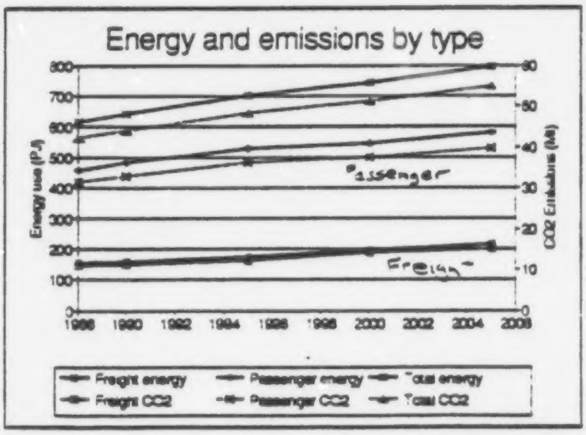
Mt/a	1988	1990	1995	2000	2005
Auto	20.1	21.3	23.3	23.7	24.9
Light truck	3.2	3.3	3.5	3.8	4.1
Truck	10.7	11.0	11.8	13.1	13.9
Airplane	4.2	4.3	5.0	5.4	6.1
Rail	1.6	1.6	1.8	2.0	2.2
Marine	1.3	1.3	1.5	1.6	1.8
Other	0.6	0.6	0.7	0.8	0.9
Bus	0.5	0.6	0.6	0.7	0.7
Streetcar & subway	0.0	0.0	0.0	0.0	0.0
GO-train	0.1	0.1	0.1	0.1	0.1
	42.3	44.0	48.3	51.2	54.7

Table 16



PJ/a	1988	1990	1995	2000	2005
Urban	301	317	343	351	365
Inter-city	314	323	360	392	429
Total	615	641	702	744	794
CO_2 emissions (Mt/a)					
Urban	20	22	23	24	25
Inter-city	22	22	25	27	30
Total	42	44	48	51	55

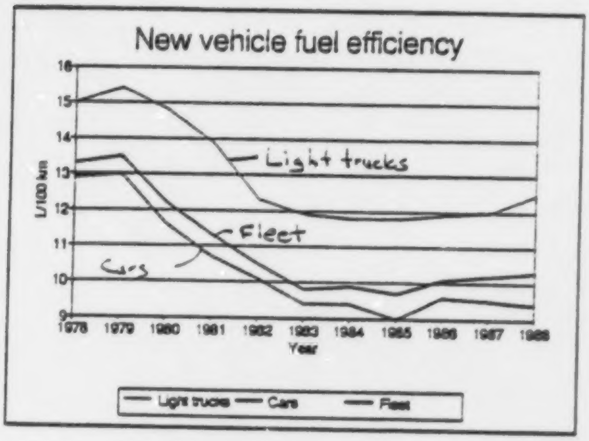
Table 17



PJ/a	1988	1990	1995	2000	2005
Freight	156	159	174	198	215
Passenger	459	481	528	546	579
Total	615	641	702	744	794
CO2 emissions (Mt/a)					
Freight	11	11	12	14	15
Passenger	31	33	36	37	40
Total	42	44	48	51	55

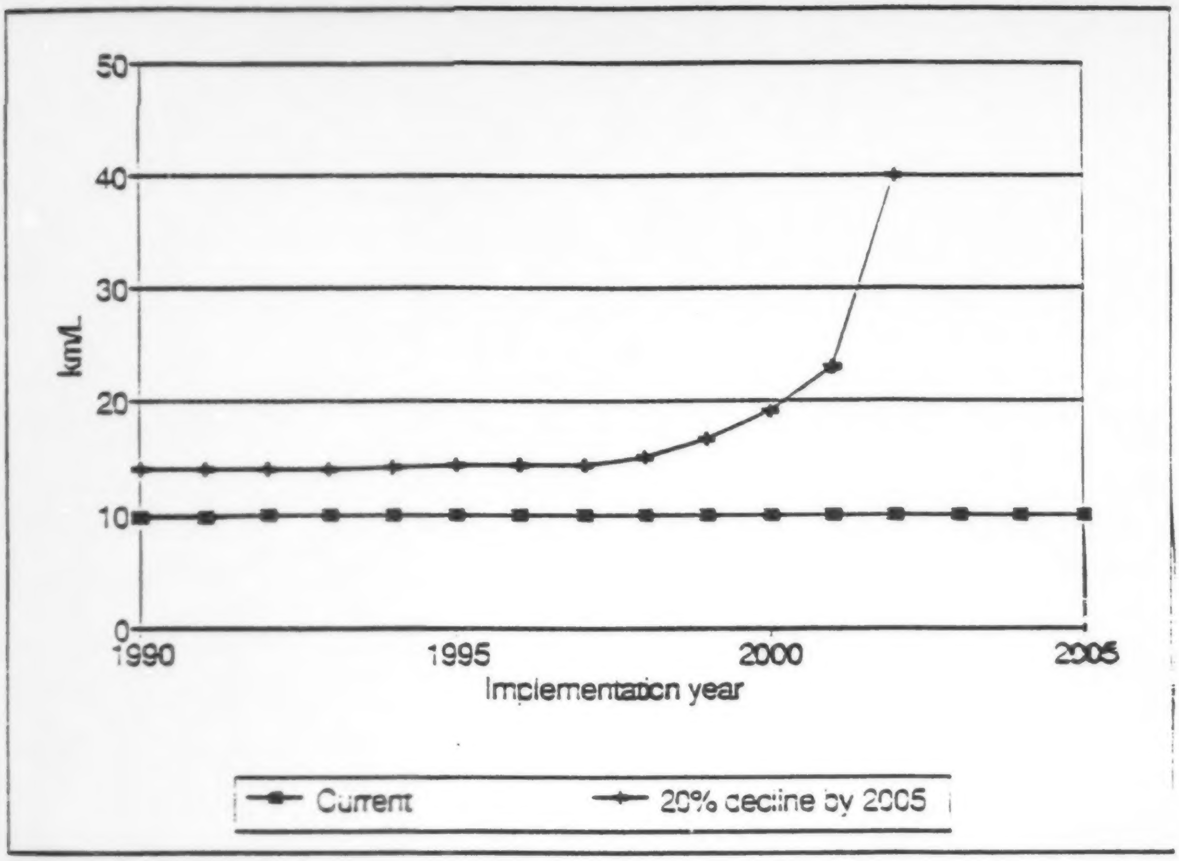
Automobile fuel economy

Table 18



L/100 km	1990	2005
Fleet average	10.76	9.52
New vehicle average	10.27	8.97
Average vehicle <1000 kg	8.80	n.a.
"Best car" on market	5.00	n.a.
Prototype vehicles	3.10	n.a.
VHB analysis	7.86	6.24

Table 19



Fuel efficiencies required to meet a fleet average objective of 20% reduction relative to 1988 levels.

Base case scenario

						Demand for Transportation						Vehicle Loading				
NUMBER	SPATIAL	SECTOR	MODE	FUEL TYPE	Units	1988	1990	1995	2000	2005	Units	1988	1990	1995	2000	2005
1	Inter city	Public	Rail	Diesel	pass km/a	1.47E+09	1.53E+09	1.72E+09	1.87E+09	2.00E+09	dimensionless	1.000	1.000	1.000	1.000	1.000
2	Inter city	Public	Bus	Diesel	pass km/a	1.54E+09	1.54E+09	1.74E+09	1.89E+09	2.08E+09	dimensionless	1.000	1.000	1.000	1.000	1.000
3	Inter city	Public	Bus	Gasoline	pass km/a	1.09E+08	1.09E+08	1.23E+08	1.33E+08	1.47E+08	dimensionless	1.000	1.000	1.000	1.000	1.000
4	Inter city	Public	Intra air	Turbo	pass km/a	4.32E+09	4.46E+09	5.05E+09	5.50E+09	6.05E+09	dimensionless	1.000	1.000	1.000	1.000	1.000
5	Inter city	Public	Extra air	Turbo	pass km/a	4.94E+06	5.01E+06	5.85E+06	6.27E+06	7.15E+06	dimensionless	1.000	1.000	1.000	1.000	1.000
6	Inter city	Private	Auto	Gasoline	pass km/a	5.90E+10	6.13E+10	6.83E+10	7.30E+10	7.93E+10	pass/veh	1.856	1.800	1.800	1.800	1.800
7	Inter city	Private	Auto	Diesel	pass km/a	9.72E+08	1.40E+09	3.45E+09	6.40E+09	9.35E+09	pass/veh	1.856	1.800	1.800	1.800	1.800
8	Inter city	Private	Light truck	Gasoline	veh km/a	3.98E+09	4.10E+09	4.71E+09	6.41E+09	6.22E+09	dimensionless	1.000	1.000	1.000	1.000	1.000
9	Inter city	Private	Light truck	Diesel	veh km/a	1.62E+08	1.72E+08	1.98E+08	2.27E+08	2.61E+08	dimensionless	1.000	1.000	1.000	1.000	1.000
10	Inter city	General freight	Truck	Gasoline	t km/a	7.96E+09	8.19E+09	9.28E+09	1.09E+10	1.25E+10	dimensionless	1.000	1.000	1.000	1.000	1.000
11	Inter city	General freight	Truck	Diesel	t km/a	2.20E+10	2.35E+10	2.98E+10	3.70E+10	4.34E+10	dimensionless	1.000	1.000	1.000	1.000	1.000
12	Inter city	General freight	Rail	Diesel	t km/a	6.08E+10	6.10E+10	7.32E+10	8.54E+10	9.80E+10	dimensionless	1.000	1.000	1.000	1.000	1.000
13	Inter city	General freight	Marine	Diesel	t km/a	1.84E+10	2.04E+10	2.98E+10	3.57E+10	4.19E+10	dimensionless	1.000	1.000	1.000	1.000	1.000
14	Inter city	General freight	Marine	Heavy F.O.	t km/a	1.44E+10	1.37E+10	1.28E+10	1.53E+10	1.80E+10	dimensionless	1.000	1.000	1.000	1.000	1.000
15	Inter city	General freight	Marine	Light F.O.	t km/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	dimensionless	1.000	1.000	1.000	1.000	1.000
16	Inter city	General freight	Marine	Kerosene	t km/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	dimensionless	1.000	1.000	1.000	1.000	1.000
17	Inter city	General freight	Marine	Coal	t km/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	dimensionless	1.000	1.000	1.000	1.000	1.000
18	Inter city	Specific freight	Rail	Diesel	t km/a	2.32E+10	2.40E+10	2.66E+10	3.10E+10	3.50E+10	dimensionless	1.000	1.000	1.000	1.000	1.000
19	Inter city	Specific freight	Marine	Diesel	t km/a	2.80E+10	3.22E+10	4.03E+10	4.29E+10	4.63E+10	dimensionless	1.000	1.000	1.000	1.000	1.000
20	Inter city	Specific freight	Marine	Heavy F.O.	t km/a	2.28E+10	2.15E+10	1.73E+10	1.84E+10	1.98E+10	dimensionless	1.000	1.000	1.000	1.000	1.000
21	Inter city	Specific freight	Marine	Light F.O.	t km/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	dimensionless	1.000	1.000	1.000	1.000	1.000
22	Inter city	Specific freight	Marine	Kerosene	t km/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	dimensionless	1.000	1.000	1.000	1.000	1.000
23	Inter city	Specific freight	Marine	Coal	t km/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	dimensionless	1.000	1.000	1.000	1.000	1.000
24	Urban	Public	Streetcar&Subway	Electricity	pass km/a	2.70E+09	2.81E+09	3.15E+09	3.41E+09	3.73E+09	dimensionless	1.000	1.000	1.000	1.000	1.000
25	Urban	Public	GO Train	Diesel	pass /a	2.84E+07	2.95E+07	3.30E+07	3.58E+07	3.91E+07	pass /veh km	1.768	1.768	1.768	1.768	1.768
26	Urban	Public	Bus	Diesel	pass km/a	2.87E+09	3.06E+09	3.45E+09	3.74E+09	4.10E+09	dimensionless	1.000	1.000	1.000	1.000	1.000
27	Urban	Public	Bus	Gasoline	pass km/a	3.38E+06	3.52E+06	3.95E+06	4.31E+06	4.73E+06	dimensionless	1.000	1.000	1.000	1.000	1.000
28	Urban	Private passenger	Auto	Electricity	pass km/a	2.16E+06	4.60E+05	5.54E+06	1.74E+07	3.29E+07	pass/veh	1.468	1.400	1.400	1.400	1.400
29	Urban	Private passenger	Auto	Diesel	pass km/a	4.40E+08	6.29E+08	1.54E+09	2.85E+09	4.14E+09	pass/veh	1.468	1.400	1.400	1.400	1.400
30	Urban	Private passenger	Auto	Gasoline	pass km/a	6.24E+10	6.46E+10	7.13E+10	7.56E+10	8.17E+10	pass/veh	1.468	1.400	1.400	1.400	1.400
31	Urban	Private passenger	Light truck	Gasoline	veh km/a	3.77E+09	3.94E+09	4.52E+09	5.19E+09	5.98E+09	dimensionless	1.000	1.000	1.000	1.000	1.000
32	Urban	Private passenger	Light truck	Diesel	veh km/a	1.30E+08	1.60E+08	1.90E+08	2.18E+08	2.50E+08	dimensionless	1.000	1.000	1.000	1.000	1.000
33	Urban	Non freight	Truck	Gasoline	veh km/a	4.80E+09	5.00E+09	5.19E+09	5.26E+09	5.04E+09	dimensionless	1.000	1.000	1.000	1.000	1.000
34	Urban	Non freight	Truck	Diesel	veh km/a	2.64E+08	3.32E+08	5.37E+08	7.14E+08	8.44E+08	dimensionless	1.000	1.000	1.000	1.000	1.000
35	Urban	Freight	Truck	Gasoline	t km/a	3.08E+09	3.16E+09	3.16E+09	2.02E+09	2.55E+09	dimensionless	1.000	1.000	1.000	1.000	1.000
36	Urban	Freight	Truck	Diesel	t km/a	2.30E+09	2.43E+09	2.82E+09	3.37E+09	3.87E+09	dimensionless	1.000	1.000	1.000	1.000	1.000
37	Aviation	General	Airplane	Turbo	MJ/a	1.14E+09	1.16E+09	1.34E+09	1.44E+09	1.63E+09	dimensionless	1.000	1.000	1.000	1.000	1.000
38	Aviation	General	Airplane	Aviation gas	MJ/a	2.15E+09	2.20E+09	2.54E+09	2.73E+09	3.07E+09	dimensionless	1.000	1.000	1.000	1.000	1.000
39	Aviation	Government	Airplane	Turbo	MJ/a	5.13E+09	5.20E+09	6.06E+09	6.52E+09	7.34E+09	dimensionless	1.000	1.000	1.000	1.000	1.000
40	Aviation	Government	Airplane	Aviation gas	MJ/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	dimensionless	1.000	1.000	1.000	1.000	1.000
41	Other	Private	Motorcycle	Gasoline	MJ/a	6.38E+08	6.80E+08	7.96E+08	9.31E+08	1.09E+09	dimensionless	1.000	1.000	1.000	1.000	1.000
42	Other	Other	School bus	Gasoline	MJ/a	1.43E+09	1.42E+09	1.39E+09	1.36E+09	1.33E+09	dimensionless	1.000	1.000	1.000	1.000	1.000
43	Other	Private	Leisure vehicle	Gasoline	MJ/a	6.57E+09	7.00E+09	8.19E+09	9.58E+09	1.12E+10	dimensionless	1.000	1.000	1.000	1.000	1.000
	TOTAL															

Base case scenario

NUMBER	SPATIAL	SECTOR	MODE	FUEL TYPE	Units	Vehicle Demand 1988	1990	1995	2000	2005	Units	Vehicle Efficiency 1988	1990	1995	2000	2005
1	Inter city	Public	Rail	Diesel	pass km/a	1.47E+09	1.53E+09	1.72E+09	1.87E+09	2.06E+09	MJ/pass km	1.733	1.733	1.733	1.733	1.733
2	Inter city	Public	Bus	Diesel	pass km/a	1.54E+09	1.54E+09	1.74E+09	1.89E+09	2.08E+09	MJ/pass km	0.869	0.869	0.869	0.869	0.869
3	Inter city	Public	Bus	Gasoline	pass km/a	1.09E+08	1.09E+08	1.23E+08	1.33E+08	1.47E+08	MJ/pass km	0.917	0.917	0.917	0.917	0.917
4	Inter city	Public	Inter air	Turbo	pass km/a	4.32E+09	4.49E+09	5.05E+09	5.50E+09	6.05E+09	MJ/pass km	4.591	4.591	4.591	4.591	4.591
5	Inter city	Public	Local air	Turbo	pass km/a	4.94E+06	5.01E+06	5.85E+06	6.27E+06	7.15E+06	MJ/pass km	6384.4	6384.4	6384.4	6384.4	6384.4
6	Inter city	Private	Auto	Gasoline	veh km/a	3.18E+10	3.40E+10	3.76E+10	4.02E+10	4.41E+10	MJ/veh km	3.093	3.012	2.842	2.766	2.663
7	Inter city	Private	Auto	Diesel	veh km/a	5.24E+08	7.80E+08	1.91E+09	3.56E+09	5.19E+09	MJ/veh km	1.304	1.223	1.128	1.086	1.073
8	Inter city	Private	Light truck	Gasoline	veh km/a	3.96E+09	4.10E+09	4.71E+09	5.41E+09	6.22E+09	MJ/veh km	5.855	5.738	5.407	5.090	4.801
9	Inter city	Private	Light truck	Diesel	veh km/a	1.62E+08	1.73E+08	1.98E+08	2.27E+08	2.61E+08	MJ/veh km	5.079	4.927	4.643	4.371	4.119
10	Inter city	General freight	Truck	Gasoline	t km/a	7.86E+09	8.18E+09	9.28E+09	1.06E+10	1.25E+10	MJ/t km	5.166	5.063	4.767	4.649	4.534
11	Inter city	General freight	Truck	Diesel	t km/a	2.20E+10	2.35E+10	2.98E+10	3.78E+10	4.34E+10	MJ/t km	1.817	1.763	1.593	1.515	1.441
12	Inter city	General freight	Rail	Diesel	t km/a	6.08E+10	6.19E+10	7.32E+10	8.54E+10	9.80E+10	MJ/t km	0.242	0.237	0.225	0.214	0.204
13	Inter city	General freight	Marine	Diesel	t km/a	1.84E+10	2.06E+10	2.98E+10	3.57E+10	4.19E+10	MJ/t km	0.213	0.204	0.185	0.180	0.175
14	Inter city	General freight	Marine	Heavy FO	t km/a	1.44E+10	1.37E+10	1.28E+10	1.53E+10	1.60E+10	MJ/t km	0.430	0.430	0.430	0.430	0.430
15	Inter city	General freight	Marine	Light FO	t km/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	MJ/t km	0.430	0.430	0.430	0.430	0.430
16	Inter city	General freight	Marine	Kerosene	t km/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	MJ/t km	0.430	0.430	0.430	0.430	0.430
17	Inter city	General freight	Marine	Coal	t km/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	MJ/t km	0.430	0.430	0.430	0.430	0.430
18	Inter city	Specific freight	Rail	Diesel	t km/a	2.33E+10	2.40E+10	2.66E+10	3.10E+10	3.50E+10	MJ/t km	0.242	0.237	0.225	0.214	0.204
19	Inter city	Specific freight	Marine	Diesel	t km/a	2.90E+10	3.23E+10	4.03E+10	4.29E+10	4.63E+10	MJ/t km	0.253	0.243	0.220	0.214	0.209
20	Inter city	Specific freight	Marine	Heavy FO	t km/a	2.20E+10	2.15E+10	1.73E+10	1.84E+10	1.98E+10	MJ/t km	0.000	0.000	0.000	0.000	0.000
21	Inter city	Specific freight	Marine	Light FO	t km/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	MJ/t km	0.000	0.000	0.000	0.000	0.000
22	Inter city	Specific freight	Marine	Kerosene	t km/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	MJ/t km	0.000	0.000	0.000	0.000	0.000
23	Inter city	Specific freight	Marine	Coal	t km/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	MJ/t km	0.000	0.000	0.000	0.000	0.000
24	Urban	Public	Streetcar&Subway	Electricity	pass km/a	2.70E+09	2.81E+09	3.15E+09	3.41E+09	3.73E+09	MJ/pass km	0.451	0.449	0.445	0.441	0.436
25	Urban	Public	GO Train	Diesel	pass km/a	1.61E+07	1.67E+07	1.87E+07	2.02E+07	2.21E+07	MJ/pass km	60.025	59.000	56.783	54.575	52.453
26	Urban	Public	Bus	Diesel	pass km/a	2.97E+09	3.09E+09	3.45E+09	3.74E+09	4.10E+09	MJ/pass km	2.109	2.109	2.109	2.109	2.109
27	Urban	Public	Bus	Gasoline	pass km/a	3.30E+06	3.53E+06	3.95E+06	4.31E+06	4.73E+06	MJ/pass km	2.227	2.227	2.227	2.227	2.227
28	Urban	Private passenger	Auto	Electricity	veh km/a	1.47E+06	3.20E+05	3.94E+06	1.25E+07	2.35E+07	MJ/veh km	0.582	3.284	1.565	1.940	2.000
29	Urban	Private passenger	Auto	Diesel	veh km/a	3.00E+08	4.40E+08	1.10E+09	2.03E+09	2.86E+09	MJ/veh km	3.957	3.743	3.433	3.293	3.234
30	Urban	Private passenger	Auto	Gasoline	veh km/a	4.25E+10	4.61E+10	5.09E+10	5.42E+10	5.84E+10	MJ/veh km	4.585	4.503	4.427	4.163	3.990
31	Urban	Private passenger	Light truck	Gasoline	veh km/a	3.77E+09	3.94E+09	4.53E+09	5.19E+09	5.96E+09	MJ/veh km	5.829	5.738	5.407	5.090	4.801
32	Urban	Private passenger	Light truck	Diesel	veh km/a	1.30E+08	1.60E+08	1.90E+08	2.18E+08	2.50E+08	MJ/veh km	5.011	4.927	4.643	4.371	4.119
33	Urban	Non freight	Truck	Gasoline	veh km/a	4.80E+09	5.00E+09	5.19E+09	5.26E+09	5.04E+09	MJ/veh km	7.245	7.133	6.782	6.610	6.452
34	Urban	Non freight	Truck	Diesel	veh km/a	2.64E+08	3.32E+08	5.37E+08	7.14E+08	8.44E+08	MJ/veh km	5.664	5.569	5.427	5.171	4.907
35	Urban	Freight	Truck	Gasoline	t km/a	3.08E+09	3.16E+09	3.16E+09	2.92E+09	2.55E+09	MJ/t km	4.190	4.124	3.923	3.838	3.730
36	Urban	Freight	Truck	Diesel	t km/a	2.30E+09	2.49E+09	2.82E+09	3.37E+09	3.87E+09	MJ/t km	10.298	10.104	9.853	9.378	8.877
37	Aviation	General	Airplane	Turbo	MJ/a	1.14E+09	1.16E+09	1.34E+09	1.44E+09	1.63E+09	dimensionless	1.000	1.000	1.000	1.000	1.000
38	Aviation	General	Airplane	Aviation gas	MJ/a	2.15E+09	2.20E+09	2.54E+09	2.73E+09	3.07E+09	dimensionless	1.000	1.000	1.000	1.000	1.000
39	Aviation	Government	Airplane	Turbo	MJ/a	5.13E+09	5.20E+09	6.06E+09	6.52E+09	7.34E+09	dimensionless	1.000	1.000	1.000	1.000	1.000
40	Aviation	Government	Airplane	Aviation gas	MJ/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	dimensionless	1.000	1.000	1.000	1.000	1.000
41	Other	Private	Motorcycle	Gasoline	MJ/a	6.38E+08	6.80E+08	7.96E+08	9.31E+08	1.09E+09	dimensionless	1.000	1.000	1.000	1.000	1.000
42	Other	Other	School bus	Gasoline	MJ/a	1.43E+09	1.42E+09	1.39E+09	1.36E+09	1.33E+09	dimensionless	1.000	1.000	1.000	1.000	1.000
43	Other	Private	Leisure vehicle	Gasoline	MJ/a	6.57E+09	7.00E+09	8.19E+09	9.59E+09	1.12E+10	dimensionless	1.000	1.000	1.000	1.000	1.000
	TOTAL					3.28E+11	3.38E+11	3.88E+11	4.40E+11	4.94E+11						

Base case scenario

NUMBER	SPATIAL	SECTOR	MODE	FUEL TYPE	Units	Energy Use 1988	1990	1995	2000	2005
1	Inter city	Public	Rail	Diesel	MJ/a	2.55E+09	2.65E+09	2.96E+09	3.25E+09	3.58E+09
2	Inter city	Public	Bus	Diesel	MJ/a	1.34E+09	1.34E+09	1.51E+09	1.64E+09	1.81E+09
3	Inter city	Public	Bus	Gasoline	MJ/a	9.90E+07	9.95E+07	1.13E+08	1.22E+08	1.35E+08
4	Inter city	Public	Intra air	Turbo	MJ/a	1.90E+10	2.06E+10	2.34E+10	2.52E+10	2.78E+10
5	Inter city	Public	Extra air	Turbo	MJ/a	3.15E+10	3.20E+10	3.74E+10	4.00E+10	4.57E+10
6	Inter city	Private	Auto	Gasoline	MJ/a	9.83E+10	1.03E+11	1.11E+11	1.12E+11	1.17E+11
7	Inter city	Private	Auto	Diesel	MJ/a	6.83E+08	9.54E+08	2.16E+09	3.86E+09	5.57E+09
8	Inter city	Private	Light truck	Gasoline	MJ/a	2.33E+10	2.35E+10	2.55E+10	2.75E+10	2.99E+10
9	Inter city	Private	Light truck	Diesel	MJ/a	8.20E+08	8.45E+08	9.10E+08	9.93E+08	1.07E+09
10	Inter city	General freight	Truck	Gasoline	MJ/a	4.11E+10	4.15E+10	4.43E+10	5.07E+10	5.66E+10
11	Inter city	General freight	Truck	Diesel	MJ/a	4.00E+10	4.14E+10	4.75E+10	5.73E+10	6.25E+10
12	Inter city	General freight	Rail	Diesel	MJ/a	1.47E+10	1.47E+10	1.65E+10	1.83E+10	1.99E+10
13	Inter city	General freight	Marine	Diesel	MJ/a	3.91E+09	4.20E+09	5.50E+09	6.42E+09	7.36E+09
14	Inter city	General freight	Marine	Heavy F.O.	MJ/a	6.22E+09	5.91E+09	5.50E+09	6.59E+09	7.73E+09
15	Inter city	General freight	Marine	Light F.O.	MJ/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
16	Inter city	General freight	Marine	Kerosene	MJ/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
17	Inter city	General freight	Marine	Coal	MJ/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
18	Inter city	Specific freight	Rail	Diesel	MJ/a	5.61E+09	5.68E+09	6.00E+09	6.64E+09	7.12E+09
19	Inter city	Specific freight	Marine	Diesel	MJ/a	7.36E+09	7.84E+09	8.84E+09	9.21E+09	9.60E+09
20	Inter city	Specific freight	Marine	Heavy F.O.	MJ/a	6.85E+03	6.44E+03	5.19E+03	5.53E+03	5.90E+03
21	Inter city	Specific freight	Marine	Light F.O.	MJ/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
22	Inter city	Specific freight	Marine	Kerosene	MJ/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
23	Inter city	Specific freight	Marine	Coal	MJ/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
24	Urban	Public	Streetcar&subway	Electricity	MJ/a	1.22E+09	1.24E+09	1.40E+09	1.50E+09	1.63E+09
25	Urban	Public	GO Train	Diesel	MJ/a	9.64E+08	9.86E+08	1.04E+09	1.10E+09	1.16E+09
26	Urban	Public	Bus	Diesel	MJ/a	6.27E+09	6.51E+09	7.26E+09	7.90E+09	8.64E+09
27	Urban	Public	Bus	Gasoline	MJ/a	7.53E+06	7.83E+06	8.81E+06	9.56E+06	1.05E+07
28	Urban	Private passenger	Auto	Electricity	MJ/a	8.70E+05	1.00E+06	6.19E+06	2.43E+07	4.73E+07
29	Urban	Private passenger	Auto	Diesel	MJ/a	1.19E+09	1.60E+09	3.77E+09	6.70E+09	9.57E+09
30	Urban	Private passenger	Auto	Gasoline	MJ/a	1.95E+11	2.00E+11	2.25E+11	2.20E+11	2.33E+11
31	Urban	Private passenger	Light truck	Gasoline	MJ/a	2.20E+10	2.24E+10	2.45E+10	2.64E+10	2.87E+10
32	Urban	Private passenger	Light truck	Diesel	MJ/a	6.54E+08	8.16E+08	8.83E+08	9.53E+08	1.03E+09
33	Urban	Non freight	Truck	Gasoline	MJ/a	3.48E+10	3.57E+10	3.52E+10	3.47E+10	3.25E+10
34	Urban	Non freight	Truck	Diesel	MJ/a	1.56E+09	1.85E+09	2.92E+09	3.66E+09	4.14E+09
35	Urban	Freight	Truck	Gasoline	MJ/a	1.28E+10	1.30E+10	1.24E+10	1.12E+10	9.51E+09
36	Urban	Freight	Truck	Diesel	MJ/a	2.43E+10	2.51E+10	2.78E+10	3.16E+10	3.45E+10
37	Aviation	General	Airplane	Turbo	MJ/a	1.14E+09	1.16E+09	1.34E+09	1.44E+09	1.63E+09
38	Aviation	General	Airplane	Aviation gas	MJ/a	2.15E+09	2.24E+09	2.54E+09	2.73E+09	3.07E+09
39	Aviation	Government	Airplane	Turbo	MJ/a	5.13E+09	5.34E+09	6.06E+09	6.52E+09	7.34E+09
40	Aviation	Government	Airplane	Aviation gas	MJ/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
41	Other	Private	Motorcycle	Gasoline	MJ/a	6.38E+08	6.60E+08	7.90E+08	9.31E+08	1.09E+09
42	Other	Other	School bus	Gasoline	MJ/a	1.48E+09	1.42E+09	1.30E+09	1.36E+09	1.33E+09
43	Other	Private	Leisure vehicle	Gasoline	MJ/a	6.57E+09	7.04E+09	8.10E+09	9.59E+09	1.12E+10
TOTAL					MJ/a	6.15E+11	6.41E+11	7.02E+11	7.44E+11	7.94E+11

Emission factors by pollutant and transportation mode

						CO2 Emissions Factors (F)						SO2 Emissions Factors (F)				
number	Spatial	Sector	Mode	Fuel type	Units	1988	1990	1995	2000	2005	Units	1988	1990	1995	2000	2005
1	INTER CITY	PUBLIC	RAIL	DIESEL	g/MJ	70.68	70.68	70.68	70.68	70.68	g/MJ	0.11	0.11	0.11	0.11	0.11
2	INTER CITY	PUBLIC	BUS	DIESEL	g/MJ	70.68	70.68	70.68	70.68	70.68	g/pass km	0.40	0.40	0.40	0.40	0.40
3	INTER CITY	PUBLIC	BUS	GASOLINE	g/MJ	67.97	67.97	67.97	67.97	67.97	g/pass km	0.40	0.40	0.40	0.40	0.40
4	INTER CITY	PUBLIC	INTRA AIR	TURBO	g/MJ	70.83	70.83	70.83	70.83	70.83	g/MJ	0.00	0.00	0.00	0.00	0.00
5	INTER CITY	PUBLIC	EXTRA AIR	TURBO	g/MJ	70.83	70.83	70.83	70.83	70.83	g/MJ	0.00	0.00	0.00	0.00	0.00
6	INTER CITY	PRIVATE	AUTO	GASOLINE	g/MJ	67.97	67.97	67.97	67.97	67.97	g/veh km	0.08	0.08	0.08	0.08	0.08
7	INTER CITY	PRIVATE	AUTO	DIESEL	g/MJ	70.68	70.68	70.68	70.68	70.68	g/veh km	0.34	0.34	0.34	0.34	0.34
8	INTER CITY	PRIVATE	LIGHT TRUCK	GASOLINE	g/MJ	67.97	67.97	67.97	67.97	67.97	g/veh km	0.11	0.11	0.11	0.11	0.11
9	INTER CITY	PRIVATE	LIGHT TRUCK	DIESEL	g/MJ	70.68	70.68	70.68	70.68	70.68	g/veh km	0.34	0.34	0.34	0.34	0.34
10	INTER CITY	GENERAL FREIGHT	TRUCK	GASOLINE	g/MJ	67.97	67.97	67.97	67.97	67.97	g/t km	0.01	0.01	0.01	0.01	0.01
11	INTER CITY	GENERAL FREIGHT	TRUCK	DIESEL	g/MJ	70.68	70.68	70.68	70.68	70.68	g/t km	0.27	0.27	0.27	0.27	0.27
12	INTER CITY	GENERAL FREIGHT	RAIL	DIESEL	g/MJ	70.68	70.68	70.68	70.68	70.68	g/MJ	0.11	0.11	0.11	0.11	0.11
13	INTER CITY	GENERAL FREIGHT	MARINE	DIESEL	g/MJ	70.68	70.68	70.68	70.68	70.68	g/MJ	0.21	0.21	0.21	0.21	0.21
14	INTER CITY	GENERAL FREIGHT	MARINE	HEAVY FO	g/MJ	80.65	80.65	80.65	80.65	80.65	g/MJ	0.69	0.69	0.69	0.69	0.69
15	INTER CITY	GENERAL FREIGHT	MARINE	LIGHT FO	g/MJ	73.11	73.11	73.11	73.11	73.11	g/MJ	0.69	0.69	0.69	0.69	0.69
16	INTER CITY	GENERAL FREIGHT	MARINE	KEROSENE	g/MJ	0.00	0.00	0.00	0.00	0.00	g/MJ	0.00	0.00	0.00	0.00	0.00
17	INTER CITY	GENERAL FREIGHT	MARINE	COAL	g/MJ	0.00	0.00	0.00	0.00	0.00	g/MJ	0.00	0.00	0.00	0.00	0.00
18	INTER CITY	SPECIFIC FREIGHT	RAIL	DIESEL	g/MJ	70.68	70.68	70.68	70.68	70.68	g/MJ	0.11	0.11	0.11	0.11	0.11
19	INTER CITY	SPECIFIC FREIGHT	MARINE	DIESEL	g/MJ	70.68	70.68	70.68	70.68	70.68	g/MJ	0.21	0.21	0.21	0.21	0.21
20	INTER CITY	SPECIFIC FREIGHT	MARINE	HEAVY FO	g/MJ	80.65	80.65	80.65	80.65	80.65	g/MJ	0.69	0.69	0.69	0.69	0.69
21	INTER CITY	SPECIFIC FREIGHT	MARINE	LIGHT FO	g/MJ	73.11	73.11	73.11	73.11	73.11	g/MJ	0.69	0.69	0.69	0.69	0.69
22	INTER CITY	SPECIFIC FREIGHT	MARINE	KEROSENE	g/MJ	0.00	0.00	0.00	0.00	0.00	g/MJ	0.00	0.00	0.00	0.00	0.00
23	INTER CITY	SPECIFIC FREIGHT	MARINE	COAL	g/MJ	0.00	0.00	0.00	0.00	0.00	g/MJ	0.00	0.00	0.00	0.00	0.00
24	URBAN	PUBLIC	STREETCAR&SUBWAY	ELECTRICITY	g/MJ	0.00	0.00	0.00	0.00	0.00	g/MJ	0.00	0.00	0.00	0.00	0.00
25	URBAN	PUBLIC	GO TRAIN	DIESEL	g/MJ	70.68	70.68	70.68	70.68	70.68	g/MJ	0.11	0.11	0.11	0.11	0.11
26	URBAN	PUBLIC	BUS	DIESEL	g/MJ	70.68	70.68	70.68	70.68	70.68	g/pass km	0.40	0.40	0.40	0.40	0.40
27	URBAN	PUBLIC	BUS	GASOLINE	g/MJ	67.97	67.97	67.97	67.97	67.97	g/pass km	0.40	0.40	0.40	0.40	0.40
28	URBAN	PRIVATE PASSENGER	AUTO	ELECTRICITY	g/MJ	0.00	0.00	0.00	0.00	0.00	g/MJ	0.00	0.00	0.00	0.00	0.00
29	URBAN	PRIVATE PASSENGER	AUTO	DIESEL	g/MJ	70.68	70.68	70.68	70.68	70.68	g/veh km	0.34	0.34	0.34	0.34	0.34
30	URBAN	PRIVATE PASSENGER	AUTO	GASOLINE	g/MJ	67.97	67.97	67.97	67.97	67.97	g/veh km	0.08	0.08	0.08	0.08	0.08
31	URBAN	PRIVATE PASSENGER	LIGHT TRUCK	GASOLINE	g/MJ	67.97	67.97	67.97	67.97	67.97	g/veh km	0.11	0.11	0.11	0.11	0.11
32	URBAN	PRIVATE PASSENGER	LIGHT TRUCK	DIESEL	g/MJ	70.68	70.68	70.68	70.68	70.68	g/veh km	0.34	0.34	0.34	0.34	0.34
33	URBAN	NON FREIGHT	TRUCK	GASOLINE	g/MJ	67.97	67.97	67.97	67.97	67.97	g/veh km	0.11	0.11	0.11	0.11	0.11
34	URBAN	NON FREIGHT	TRUCK	DIESEL	g/MJ	70.68	70.68	70.68	70.68	70.68	g/veh km	0.34	0.34	0.34	0.34	0.34
35	URBAN	FREIGHT	TRUCK	GASOLINE	g/MJ	67.97	67.97	67.97	67.97	67.97	g/t km	0.01	0.01	0.01	0.01	0.01
36	URBAN	FREIGHT	TRUCK	DIESEL	g/MJ	70.68	70.68	70.68	70.68	70.68	g/t km	0.27	0.27	0.27	0.27	0.27
37	AVIATION	GENERAL	AIRPLANE	TURBO	g/MJ	70.83	70.83	70.83	70.83	70.83	g/MJ	0.00	0.00	0.00	0.00	0.00
38	AVIATION	GENERAL	AIRPLANE	AVIATION GAS	g/MJ	75.92	75.92	75.92	75.92	75.92	g/MJ	0.00	0.00	0.00	0.00	0.00
39	AVIATION	GOVERNMENT	AIRPLANE	TURBO	g/MJ	70.83	70.83	70.83	70.83	70.83	g/MJ	0.00	0.00	0.00	0.00	0.00
40	AVIATION	GOVERNMENT	AIRPLANE	AVIATION GAS	g/MJ	75.92	75.92	75.92	75.92	75.92	g/MJ	0.00	0.00	0.00	0.00	0.00
41	OTHER	PRIVATE	MOTORCYCLES	GASOLINE	g/MJ	67.97	67.97	67.97	67.97	67.97	g/MJ	0.06	0.05	0.05	0.05	0.05
42	OTHER	OTHER	SCHOOL BUSES	GASOLINE	g/MJ	67.97	67.97	67.97	67.97	67.97	g/MJ	0.02	0.02	0.02	0.02	0.02
43	OTHER	PRIVATE	LEISURE VEHICLES	GASOLINE	g/MJ	67.97	67.97	67.97	67.97	67.97	g/MJ	0.02	0.02	0.02	0.02	0.02

Emission factors by pollutant and transportation mode

Number	Spatial	Sector	Mode	Fuel type	Units	NOx Emissions Factors (F) 1988	1990	1995	2000	2005	Units	VOCs Emissions Factors (F) 1988	1990	1995	2000	2005
1	INTER-CITY	PUBLIC	RAIL	DIESEL	g/MJ	1.44	1.44	1.44	1.44	1.44	g/MJ	0.07	0.07	0.07	0.07	0.07
2	INTER-CITY	PUBLIC	BUS	DIESEL	g/pass.km	3.53	2.82	2.15	1.38	1.30	g/pass.km	0.38	0.28	0.25	0.23	0.22
3	INTER-CITY	PUBLIC	BUS	GASOLINE	g/pass.km	8.42	7.63	6.91	6.19	6.10	g/pass.km	9.98	5.81	4.96	4.12	3.97
4	INTER-CITY	PUBLIC	INTRA AIR	TURBO	g/MJ	0.03	0.03	0.03	0.03	0.03	g/MJ	0.04	0.04	0.04	0.04	0.04
5	INTER-CITY	PUBLIC	EXTRA AIR	TURBO	g/MJ	0.03	0.03	0.03	0.03	0.03	g/MJ	0.04	0.04	0.04	0.04	0.04
6	INTER-CITY	PRIVATE	AUTO	GASOLINE	g/veh.km	1.97	1.28	0.95	0.63	0.60	g/veh.km	2.30	1.73	1.38	1.03	0.99
7	INTER-CITY	PRIVATE	AUTO	DIESEL	g/veh.km	1.29	1.14	1.02	0.88	0.90	g/veh.km	0.34	0.34	0.32	0.30	0.31
8	INTER-CITY	PRIVATE	LIGHT TRUCK	GASOLINE	g/veh.km	2.19	1.48	1.20	0.92	0.86	g/veh.km	3.19	2.15	1.71	1.28	1.19
9	INTER-CITY	PRIVATE	LIGHT TRUCK	DIESEL	g/veh.km	1.29	1.14	1.02	0.89	0.90	g/veh.km	0.34	0.34	0.32	0.30	0.31
10	INTER-CITY	GENERAL FREIGHT	TRUCK	GASOLINE	g/t.km	0.14	0.13	0.11	0.10	0.10	g/t.km	0.16	0.10	0.08	0.07	0.07
11	INTER-CITY	GENERAL FREIGHT	TRUCK	DIESEL	g/t.km	2.40	1.90	1.46	0.94	0.88	g/t.km	0.26	0.18	0.17	0.16	0.15
12	INTER-CITY	GENERAL FREIGHT	RAIL	DIESEL	g/MJ	1.44	1.44	1.44	1.44	1.44	g/MJ	0.07	0.07	0.07	0.07	0.07
13	INTER-CITY	GENERAL FREIGHT	MARINE	DIESEL	g/MJ	0.80	0.80	0.80	0.80	0.80	g/MJ	0.18	0.18	0.18	0.18	0.18
14	INTER-CITY	GENERAL FREIGHT	MARINE	HEAVY FO	g/MJ	0.10	0.10	0.10	0.10	0.10	g/MJ	0.01	0.01	0.01	0.01	0.01
15	INTER-CITY	GENERAL FREIGHT	MARINE	LIGHT FO	g/MJ	0.10	0.10	0.10	0.10	0.10	g/MJ	0.01	0.01	0.01	0.01	0.01
16	INTER-CITY	GENERAL FREIGHT	MARINE	KEROSENE												
17	INTER-CITY	GENERAL FREIGHT	MARINE	COAL												
18	INTER-CITY	SPECIFIC FREIGHT	RAIL	DIESEL	g/MJ	1.44	1.44	1.44	1.44	1.44	g/MJ	0.07	0.07	0.07	0.07	0.07
19	INTER-CITY	SPECIFIC FREIGHT	MARINE	DIESEL	g/MJ	0.80	0.80	0.80	0.80	0.80	g/MJ	0.18	0.18	0.18	0.18	0.18
20	INTER-CITY	SPECIFIC FREIGHT	MARINE	HEAVY FO	g/MJ	0.10	0.10	0.10	0.10	0.10	g/MJ	0.01	0.01	0.01	0.01	0.01
21	INTER-CITY	SPECIFIC FREIGHT	MARINE	LIGHT FO	g/MJ	0.10	0.10	0.10	0.10	0.10	g/MJ	0.01	0.01	0.01	0.01	0.01
22	INTER-CITY	SPECIFIC FREIGHT	MARINE	KEROSENE												
23	INTER-CITY	SPECIFIC FREIGHT	MARINE	COAL												
24	URBAN	PUBLIC	STREETCAR&SUBWAY	ELECTRICITY	g/MJ	0.00	0.00	0.00	0.00	0.00	g/MJ	0.00	0.00	0.00	0.00	0.00
25	URBAN	PUBLIC	GO-TRAIN	DIESEL	g/MJ	1.44	1.44	1.44	1.44	1.44	g/MJ	0.07	0.07	0.07	0.07	0.07
26	URBAN	PUBLIC	BUS	DIESEL	g/pass.km	3.53	2.82	2.15	1.38	1.30	g/pass.km	0.38	0.28	0.25	0.23	0.22
27	URBAN	PUBLIC	BUS	GASOLINE	g/pass.km	8.42	7.63	6.91	6.19	6.10	g/pass.km	9.98	5.81	4.96	4.12	3.97
28	URBAN	PRIVATE PASSENGER	AUTO	ELECTRICITY	g/MJ	0.00	0.00	0.00	0.00	0.00	g/MJ	0.00	0.00	0.00	0.00	0.00
29	URBAN	PRIVATE PASSENGER	AUTO	DIESEL	g/veh.km	1.29	1.14	1.02	0.88	0.90	g/veh.km	0.34	0.34	0.32	0.30	0.31
30	URBAN	PRIVATE PASSENGER	AUTO	GASOLINE	g/veh.km	1.97	1.28	0.95	0.63	0.60	g/veh.km	2.30	1.73	1.53	1.03	0.99
31	URBAN	PRIVATE PASSENGER	LIGHT TRUCK	GASOLINE	g/veh.km	2.19	1.48	1.20	0.92	0.86	g/veh.km	3.19	2.15	1.71	1.28	1.19
32	URBAN	PRIVATE PASSENGER	LIGHT TRUCK	DIESEL	g/veh.km	1.29	1.14	1.02	0.88	0.90	g/veh.km	0.34	0.34	0.32	0.30	0.31
33	URBAN	NON FREIGHT	TRUCK	GASOLINE	g/veh.km	2.83	2.00	1.80	1.60	1.51	g/veh.km	4.75	3.20	2.28	1.31	1.24
34	URBAN	NON FREIGHT	TRUCK	DIESEL	g/veh.km	1.29	1.14	1.02	0.89	0.90	g/veh.km	0.34	0.34	0.32	0.30	0.31
35	URBAN	FREIGHT	TRUCK	GASOLINE	g/t.km	0.14	0.13	0.11	0.10	0.10	g/t.km	0.16	0.10	0.08	0.07	0.07
36	URBAN	FREIGHT	TRUCK	DIESEL	g/t.km	2.40	1.90	1.46	0.94	0.88	g/t.km	0.26	0.18	0.17	0.16	0.15
37	AVIATION	GENERAL	AIRPLANE	TURBO	g/MJ	0.03	0.03	0.03	0.03	0.03	g/MJ	0.04	0.04	0.04	0.04	0.04
38	AVIATION	GENERAL	AIRPLANE	AVIATION GAS	g/MJ	0.03	0.03	0.03	0.03	0.03	g/MJ	0.04	0.04	0.04	0.04	0.04
39	AVIATION	GOVERNMENT	AIRPLANE	TURBO	g/MJ	0.03	0.03	0.03	0.03	0.03	g/MJ	0.04	0.04	0.04	0.04	0.04
40	AVIATION	GOVERNMENT	AIRPLANE	AVIATION GAS	g/MJ	0.03	0.03	0.03	0.03	0.03	g/MJ	0.04	0.04	0.04	0.04	0.04
41	OTHER	PRIVATE	MOTORCYCLES	GASOLINE	g/MJ	1.21	0.77	0.58	0.39	0.37	g/MJ	1.41	1.08	1.23	0.83	0.61
42	OTHER	OTHER	SCHOOL BUSES	GASOLINE	g/MJ	0.47	0.42	0.38	0.34	0.34	g/MJ	0.55	0.32	0.44	0.23	0.22
43	OTHER	PRIVATE	LEISURE VEHICLES	GASOLINE	g/MJ	0.48	0.33	0.30	0.26	0.25	g/MJ	0.78	0.53	0.65	0.22	[illegible]

Emission factors by pollutant and transportation mode

					Particulate Emissions Factors (F)						CO Emissions Factors (F)					
Number	Spatial	Sector	Mode	Fuel type	Units	1988	1990	1995	2000	2005	Units	1988	1990	1995	2000	2005
1	INTER CITY	PUBLIC	RAIL	DIESEL	g/MJ	0.08	0.08	0.08	0.08	0.08	g/MJ	0.57	0.57	0.57	0.57	0.57
2	INTER CITY	PUBLIC	BUS	DIESEL	g/pass km	0.19	0.19	0.19	0.19	0.19	g/pass km	1.56	1.37	1.29	1.22	1.21
3	INTER CITY	PUBLIC	BUS	GASOLINE	g/pass km	1.25	1.25	1.25	1.25	1.25	g/pass km	112.38	64.16	48.47	32.78	30.05
4	INTER CITY	PUBLIC	INTRA AIR	TURBO	g/MJ	0.00	0.00	0.00	0.00	0.00	g/MJ	0.11	0.11	0.11	0.11	0.11
5	INTER CITY	PUBLIC	EXTRA AIR	TURBO	g/MJ	0.00	0.00	0.00	0.00	0.00	g/MJ	0.11	0.11	0.11	0.11	0.11
6	INTER CITY	PRIVATE	AUTO	GASOLINE	g/veh km	0.34	0.34	0.34	0.34	0.34	g/veh km	19.30	12.52	10.09	7.66	7.48
7	INTER CITY	PRIVATE	AUTO	DIESEL	g/veh km	0.45	0.45	0.45	0.45	0.45	g/veh km	0.81	0.80	0.77	0.74	0.76
8	INTER CITY	PRIVATE	LIGHT TRUCK	GASOLINE	g/veh km	0.34	0.34	0.34	0.34	0.34	g/veh km	25.11	17.38	14.21	11.00	10.53
9	INTER CITY	PRIVATE	LIGHT TRUCK	DIESEL	g/veh km	0.45	0.45	0.45	0.45	0.45	g/veh km	0.81	0.80	0.77	0.74	0.76
10	INTER CITY	GENERAL FREIGHT	TRUCK	GASOLINE	g/t km	0.02	0.02	0.02	0.02	0.02	g/t km	1.04	1.05	0.80	0.54	0.49
11	INTER CITY	GENERAL FREIGHT	TRUCK	DIESEL	g/t km	0.13	0.13	0.13	0.13	0.13	g/t km	1.08	0.93	0.86	0.83	0.82
12	INTER CITY	GENERAL FREIGHT	RAIL	DIESEL	g/MJ	0.08	0.08	0.08	0.08	0.08	g/MJ	0.57	0.57	0.57	0.57	0.57
13	INTER CITY	GENERAL FREIGHT	MARINE	DIESEL	g/MJ	0.06	0.06	0.05	0.05	0.05	g/MJ	0.34	0.34	0.34	0.34	0.34
14	INTER CITY	GENERAL FREIGHT	MARINE	HEAVY FO	g/MJ	0.03	0.03	0.03	0.03	0.03	g/MJ	0.00	0.00	0.00	0.00	0.00
15	INTER CITY	GENERAL FREIGHT	MARINE	LIGHT FO	g/MJ	0.03	0.03	0.03	0.03	0.03	g/MJ	0.00	0.00	0.00	0.00	0.00
16	INTER CITY	GENERAL FREIGHT	MARINE	KEROSENE												
17	INTER CITY	GENERAL FREIGHT	MARINE	COAL												
18	INTER CITY	SPECIFIC FREIGHT	RAIL	DIESEL	g/MJ	0.08	0.08	0.08	0.08	0.08	g/MJ	0.57	0.57	0.57	0.57	0.57
19	INTER CITY	SPECIFIC FREIGHT	MARINE	DIESEL	g/MJ	0.05	0.05	0.05	0.05	0.05	g/MJ	0.34	0.34	0.34	0.34	0.34
20	INTER CITY	SPECIFIC FREIGHT	MARINE	HEAVY FO	g/MJ	0.03	0.03	0.03	0.03	0.03	g/MJ	0.00	0.00	0.00	0.00	0.00
21	INTER CITY	SPECIFIC FREIGHT	MARINE	LIGHT FO	g/MJ	0.03	0.03	0.03	0.03	0.03	g/MJ	0.00	0.00	0.00	0.00	0.00
22	INTER CITY	SPECIFIC FREIGHT	MARINE	KEROSENE												
23	INTER CITY	SPECIFIC FREIGHT	MARINE	COAL												
24	URBAN	PUBLIC	STREETCAR&SUBWAY	ELECTRICITY	g/MJ	0.00	0.00	0.00	0.00	0.00	g/MJ	0.00	0.00	0.00	0.00	0.00
25	URBAN	PUBLIC	GO TRAIN	DIESEL	g/MJ	0.08	0.08	0.08	0.08	0.08	g/MJ	0.57	0.57	0.57	0.57	0.57
26	URBAN	PUBLIC	BUS	DIESEL	g/pass km	0.19	0.19	0.19	0.19	0.19	g/pass km	1.56	1.37	1.29	1.22	1.21
27	URBAN	PUBLIC	BUS	GASOLINE	g/pass km	1.25	1.25	1.25	1.25	1.25	g/pass km	112.38	64.16	48.47	32.78	30.05
28	URBAN	PRIVATE PASSENGER	AUTO	ELECTRICITY	g/MJ	0.00	0.00	0.00	0.00	0.00	g/MJ	0.00	0.00	0.00	0.00	0.00
29	URBAN	PRIVATE PASSENGER	AUTO	DIESEL	g/veh km	0.45	0.45	0.45	0.45	0.45	g/veh km	0.81	0.80	0.77	0.74	0.76
30	URBAN	PRIVATE PASSENGER	AUTO	GASOLINE	g/veh km	0.34	0.34	0.34	0.34	0.34	g/veh km	19.30	12.52	10.09	7.66	7.48
31	URBAN	PRIVATE PASSENGER	LIGHT TRUCK	GASOLINE	g/veh km	0.34	0.34	0.34	0.34	0.34	g/veh km	25.11	17.38	14.21	11.00	10.53
32	URBAN	PRIVATE PASSENGER	LIGHT TRUCK	DIESEL	g/veh km	0.45	0.45	0.45	0.45	0.45	g/veh km	0.81	0.80	0.77	0.74	0.76
33	URBAN	NON FREIGHT	TRUCK	GASOLINE	g/veh km	0.34	0.34	0.34	0.34	0.34	g/veh km	27.15	18.80	15.36	11.82	11.38
34	URBAN	NON FREIGHT	TRUCK	DIESEL	g/veh km	0.45	0.45	0.45	0.45	0.45	g/veh km	0.81	0.80	0.77	0.74	0.76
35	URBAN	FREIGHT	TRUCK	GASOLINE	g/t km	0.02	0.02	0.02	0.02	0.02	g/t km	1.04	1.05	0.80	0.54	0.49
36	URBAN	FREIGHT	TRUCK	DIESEL	g/t km	0.13	0.13	0.13	0.13	0.13	g/t km	1.08	0.83	0.86	0.83	0.82
37	AVIATION	GENERAL	AIRPLANE	TURBO	g/MJ	0.00	0.00	0.00	0.00	0.00	g/MJ	0.11	0.11	0.11	0.11	0.11
38	AVIATION	GENERAL	AIRPLANE	AVIATION GAS	g/MJ	0.00	0.00	0.00	0.00	0.00	g/MJ	0.11	0.11	0.11	0.11	0.11
39	AVIATION	GOVERNMENT	AIRPLANE	TURBO	g/MJ	0.00	0.00	0.00	0.00	0.00	g/MJ	0.11	0.11	0.11	0.11	0.11
40	AVIATION	GOVERNMENT	AIRPLANE	AVIATION GAS	g/MJ	0.00	0.00	0.00	0.00	0.00	g/MJ	0.11	0.11	0.11	0.11	0.11
41	OTHER	PRIVATE	MOTORCYCLES	GASOLINE	g/MJ	0.21	0.21	0.21	0.21	0.21	g/MJ	11.62	7.67	6.18	4.88	4.56
42	OTHER	OTHER	SCHOOL BUSES	GASOLINE	g/MJ	0.07	0.07	0.07	0.07	0.07	g/MJ	6.23	3.56	2.66	1.82	1.67
43	OTHER	PRIVATE	LEISURE VEHICLES	GASOLINE	g/MJ	0.06	0.06	0.06	0.06	0.06	g/MJ	4.40	3.09	2.52	1.86	1.87

Base case emissions

NUMBER	SYSTEM	SECTOR	MODE	FUEL TYPE		Base case emissions Tonnes of CO2 1988	1990	1995	2000	2005		Units	Base case emissions Tonnes of N2O Emissions (?) 1988	1990	1995	2000	2005
1	Inter-city	Public	Rail	Diesel	tonnes	180 342	187 375	211 130	228 540	252 728		tonnes	262	[illegible]	241	571	[illegible]
2	Inter-city	Public	Bus	Diesel	tonnes	94 573	94 612	[illegible]	115 820	127 614		tonnes	612	612	[illegible]	700	[illegible]
3	Inter-city	Public	Bus	Gasoline	tonnes	6 767	6 790	[illegible]	[illegible]	9 158		tonnes	44	44	50	54	59
4	Inter-city	Public	Inter air	Turbo	tonnes	[illegible]	1 458 577	1 643 415	1 707 010	[illegible]		tonnes	60	71	80	87	[illegible]
5	Inter-city	Public	Extra air	Turbo	tonnes	2 232 700	2 357 014	[illegible]	[illegible]	[illegible]		tonnes	[illegible]	111	[illegible]	[illegible]	158
6	Inter-city	Private	Auto	Gasoline	tonnes	[illegible]	[illegible]	[illegible]	[illegible]	7 574 751		tonnes	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	Inter-city	Private	Auto	Diesel	tonnes	48 280	67 468	151 078	264 787	374 285		tonnes	170	[illegible]	[illegible]	[illegible]	[illegible]
8	Inter-city	Private	Light truck	Gasoline	tonnes	[illegible]	[illegible]	1 712 870	[illegible]	[illegible]		tonnes	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	Inter-city	Private	Light truck	Diesel	tonnes	57 983	60 037	64 287	[illegible]	72 065		tonnes	56	58	67	77	[illegible]
10	Inter-city	General freight	Truck	Gasoline	tonnes	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		tonnes	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	Inter-city	General freight	Truck	Diesel	tonnes	2 825 701	2 825 785	3 323 391	3 828 721	4 188 745		tonnes	5 050	6 350	8 060	10 226	11 734
12	Inter-city	General freight	Rail	Diesel	tonnes	1 038 779	1 036 485	1 165 115	1 292 180	1 410 060		tonnes	1 679	1 676	1 884	2 088	2 280
13	Inter-city	General freight	Marine	Diesel	tonnes	276 181	207 184	368 828	454 134	518 900		tonnes	817	679	1 151	1 344	1 538
14	Inter-city	General freight	Marine	Heavy FO	tonnes	501 341	476 603	443 478	531 087	623 454		tonnes	4 268	4 057	3 775	4 521	5 307
15	Inter-city	General freight	Marine	Light FO	tonnes	0	0	0	0	0		tonnes	0	0	0	0	0
16	Inter-city	General freight	Marine	Kerosene	tonnes	0	0	0	0	0		tonnes	0	0	0	0	0
17	Inter-city	General freight	Marine	Coal	tonnes	0	0	0	0	0		tonnes	0	0	0	0	0
18	Inter-city	Specific freight	Rail	Diesel	tonnes	396 820	402 367	423 757	488 060	503 513		tonnes	642	650	685	758	814
19	Inter-city	Specific freight	Marine	Diesel	tonnes	519 088	554 396	626 498	651 106	684 243		tonnes	1 538	1 640	1 854	1 927	2 025
20	Inter-city	Specific freight	Marine	Heavy FO	tonnes	1	1	0	0	0		tonnes	0	0	0	0	0
21	Inter-city	Specific freight	Marine	Light FO	tonnes	0	0	0	0	0		tonnes	0	0	0	0	0
22	Inter-city	Specific freight	Marine	Kerosene	tonnes	0	0	0	0	0		tonnes	0	0	0	0	0
23	Inter-city	Specific freight	Marine	Coal	tonnes	0	0	0	0	0		tonnes	0	0	0	0	0
24	Urban	Public	Streetcar & Subway	Electricity	tonnes	0	0	0	0	0		tonnes	0	0	0	0	0
25	Urban	Public	GO Train	Diesel	tonnes	68 125	68 660	74 844	78 076	82 094		tonnes	110	113	121	126	133
26	Urban	Public	Bus	Diesel	tonnes	443 056	460 243	515 081	550 231	610 662		tonnes	1 181	1 227	1 373	1 488	1 626
27	Urban	Public	Bus	Gasoline	tonnes	511	532	580	652	716		tonnes	1	1	2	2	2
28	Urban	Private passenger	Auto	Electricity	tonnes	0	0	0	0	0		tonnes	0	0	0	0	0
29	Urban	Private passenger	Auto	Diesel	tonnes	83 629	118 817	263 738	458 366	642 677		tonnes	102	153	373	682	1 006
30	Urban	Private passenger	Auto	Gasoline	tonnes	13 241 454	14 118 327	15 168 262	14 875 020	15 072 010		tonnes	3 390	3 680	4 073	4 335	4 670
31	Urban	Private passenger	Light truck	Gasoline	tonnes	1 483 131	1 536 705	1 645 688	1 743 016	1 853 180		tonnes	415	433	497	571	658
32	Urban	Private passenger	Light truck	Diesel	tonnes	46 205	57 682	61 770	65 341	68 250		tonnes	44	56	65	74	85
33	Urban	Non freight	Truck	Gasoline	tonnes	2 363 984	2 424 810	2 370 421	2 298 540	2 098 201		tonnes	526	550	571	578	554
34	Urban	Non freight	Truck	Diesel	tonnes	105 714	130 850	202 987	253 182	278 010		tonnes	80	113	183	243	287
35	Urban	Freight	Truck	Gasoline	tonnes	878 445	894 956	833 705	738 005	613 831		tonnes	20	21	21	18	17
36	Urban	Freight	Truck	Diesel	tonnes	1 717 010	1 775 824	1 947 148	2 167 424	2 314 628		tonnes	638	672	764	811	1 047
37	Aviation	General	Airplane	Turbo	tonnes	80 529	82 498	85 800	102 338	115 173		tonnes	4	4	5	5	6
38	Aviation	General	Airplane	Aviation gas	tonnes	163 162	167 148	182 458	207 351	233 355		tonnes	7	8	8	9	11
39	Aviation	Government	Airplane	Turbo	tonnes	363 667	372 563	428 985	462 166	520 114		tonnes	18	18	21	23	25
40	Aviation	Government	Airplane	Aviation gas	tonnes	0	0	0	0	0		tonnes	0	0	0	0	0
41	Other	Private	Motorcycle	Gasoline	tonnes	43 381	46 202	54 083	63 308	74 106		tonnes	31	33	38	46	53
42	Other	Other	School bus	Gasoline	tonnes	87 408	86 502	84 505	82 608	80 685		tonnes	32	32	31	31	30
43	Other	Private	Leisure vehicle	Gasoline	tonnes	446 558	475 501	556 718	651 679	762 811		tonnes	110	126	148	173	203
	TOTAL					42 281 126	44 033 768	47 846 505	49 966 000	52 567 836	0	0	26 026	27 164	31 320	36 768	41 845

Base case emissions

						Base case emissions Tonnes of NOx Emissions (F)						Base case emissions Tonnes of VOCs Emissions (F)				
NUMBER	SPATIAL	SECTOR	MODE	FUEL TYPE	Units	1988	1990	1995	2000	2005	Unit	1988	1990	1995	2000	2005
1	Inter-city	Public	Rail	Diesel	tonnes	3 668	3 811	4 293	4 668	5 140	tonnes	178	165	208	227	250
2	Inter-city	Public	Bus	Diesel	tonnes	5 436	4 502	3 731	2 580	2 606	tonnes	507	425	438	432	466
3	Inter-city	Public	Bus	Gasoline	tonnes	816	830	848	826	886	tonnes	1 066	632	600	549	563
4	Inter-city	Public	Intra air	Turbo	tonnes	660	665	763	852	938	tonnes	765	765	866	874	1 072
5	Inter-city	Public	Extra air	Turbo	tonnes	1 064	1 081	1 261	1 351	1 541	tonnes	0	0	0	0	0
6	Inter-city	Private	Auto	Gasoline	tonnes	62 626	42 841	35 781	25 539	26 433	tonnes	73 117	58 622	52 251	41 749	43 614
7	Inter-city	Private	Auto	Diesel	tonnes	676	860	1 943	3 165	4 674	tonnes	178	265	613	1 067	1 610
8	Inter-city	Private	Light truck	Gasoline	tonnes	8 717	6 068	5 640	4 874	5 351	tonnes	12 668	8 816	8 026	6 812	7 404
9	Inter-city	Private	Light truck	Diesel	tonnes	208	187	201	202	235	tonnes	55	58	63	68	81
10	Inter-city	General freight	Truck	Gasoline	tonnes	1 090	1 026	1 053	1 108	1 251	tonnes	1 303	781	756	737	814
11	Inter-city	General freight	Truck	Diesel	tonnes	52 850	46 080	43 505	35 429	38 307	tonnes	5 705	4 408	5 120	5 895	6 626
12	Inter-city	General freight	Rail	Diesel	tonnes	21 125	21 078	23 604	26 278	28 676	tonnes	1 045	1 024	1 151	1 276	1 393
13	Inter-city	General freight	Marine	Diesel	tonnes	3 132	3 370	4 408	5 140	5 845	tonnes	714	769	1 005	1 174	1 344
14	Inter-city	General freight	Marine	Heavy FO	tonnes	651	619	676	680	810	tonnes	57	54	58	60	70
15	Inter-city	General freight	Marine	Light FO	tonnes	0	0	0	0	0	tonnes	0	0	0	0	0
16	Inter-city	General freight	Marine	Kerosene	tonnes	0	0	0	0	0	tonnes	0	0	0	0	0
17	Inter-city	General freight	Marine	Coal	tonnes	0	0	0	0	0	tonnes	0	0	0	0	0
18	Inter-city	Specific freight	Rail	Diesel	tonnes	8 070	8 183	8 818	9 538	10 240	tonnes	362	387	418	463	497
19	Inter-city	Specific freight	Marine	Diesel	tonnes	5 885	6 286	7 134	7 383	7 758	tonnes	1 344	1 434	1 620	1 684	1 768
20	Inter-city	Specific freight	Marine	Heavy FO	tonnes	0	0	0	0	0	tonnes	0	0	0	0	0
21	Inter-city	Specific freight	Marine	Light FO	tonnes	0	0	0	0	0	tonnes	0	0	0	0	0
22	Inter-city	Specific freight	Marine	Kerosene	tonnes	0	0	0	0	0	tonnes	0	0	0	0	0
23	Inter-city	Specific freight	Marine	Coal	tonnes	0	0	0	0	0	tonnes	0	0	0	0	0
24	Urban	Public	Streetcar&Subway	Electricity	tonnes	0	0	0	0	0	tonnes	0	0	0	0	0
25	Urban	Public	GO Train	Diesel	tonnes	1 305	1 417	1 524	1 588	1 670	tonnes	67	69	74	77	81
26	Urban	Public	Bus	Diesel	tonnes	10 488	8 019	7 425	6 156	5 313	tonnes	1 132	851	872	858	818
27	Urban	Public	Bus	Gasoline	tonnes	28	27	27	27	29	tonnes	34	20	20	18	19
28	Urban	Private passenger	Auto	Electricity	tonnes	0	0	0	0	0	tonnes	0	0	0	0	0
29	Urban	Private passenger	Auto	Diesel	tonnes	387	512	1 114	1 811	2 664	tonnes	102	153	351	610	918
30	Urban	Private passenger	Auto	Gasoline	tonnes	63 703	50 114	48 111	34 137	35 027	tonnes	97 725	79 791	70 257	56 812	57 764
31	Urban	Private passenger	Light truck	Gasoline	tonnes	8 253	5 831	5 427	4 778	5 141	tonnes	12 022	8 470	7 711	6 544	7 114
32	Urban	Private passenger	Light truck	Diesel	tonnes	168	188	183	194	225	tonnes	44	56	61	66	78
33	Urban	Non freight	Truck	Gasoline	tonnes	14 065	10 003	9 348	8 410	7 606	tonnes	22 802	16 004	11 711	6 865	6 245
34	Urban	Non freight	Truck	Diesel	tonnes	341	378	545	636	758	tonnes	80	113	172	214	262
35	Urban	Freight	Truck	Gasoline	tonnes	426	385	358	297	255	tonnes	505	301	257	198	166
36	Urban	Freight	Truck	Diesel	tonnes	5 666	4 844	4 130	3 158	3 418	tonnes	612	467	485	525	581
37	Aviation	General	Airplane	Turbo	tonnes	38	39	45	49	55	tonnes	44	45	52	56	63
38	Aviation	General	Airplane	Aviation gas	tonnes	73	74	86	92	104	tonnes	83	85	98	105	119
39	Aviation	Government	Airplane	Turbo	tonnes	173	178	204	220	248	tonnes	198	203	234	252	284
40	Aviation	Government	Airplane	Aviation gas	tonnes	0	0	0	0	0	tonnes	0	0	0	0	0
41	Other	Private	Motorcycle	Gasoline	tonnes	770	520	458	358	401	tonnes	800	720	882	580	661
42	Other	Other	School bus	Gasoline	tonnes	668	601	533	460	451	tonnes	792	457	606	311	283
43	Other	Private	Leisure vehicle	Gasoline	tonnes	3 160	2 297	2 420	2 518	2 782	tonnes	5 123	3 676	5 345	2 062	2 284
	TOTAL				0	306 567	242 704	225 480	193 646	206 887	0 0	241 480	190 347	172 518	138 347	145 485

Base case emissions

						Base case emissions Tonnes of Particulate Emissions (P)						Base case emissions Tonnes of CO Emissions (P)				
NUMBER	SPATIAL	SECTOR	MODE	FUEL TYPE	Units	1988	1990	1995	2000	2005	Units	1988	1990	1995	2000	2005
1	Inter-city	Public	Rail	Diesel	tonnes	190	206	232	252	277	tonnes	1 488	1 524	1 717	1 867	2 066
2	Inter-city	Public	Bus	Diesel	tonnes	262	282	329	357	383	tonnes	2 444	2 107	2 244	2 290	2 511
3	Inter-city	Public	Bus	Gasoline	tonnes	136	136	153	167	184	tonnes	12 230	6 866	5 846	4 373	4 412
4	Inter-city	Public	Intra air	Turbo	tonnes	56	58	65	71	78	tonnes	2 130	2 222	2 503	2 722	2 847
5	Inter-city	Public	Extra air	Turbo	tonnes	86	90	105	112	128	tonnes	3 401	3 453	4 032	4 316	4 626
6	Inter-city	Private	Auto	Gasoline	tonnes	10 808	11 560	12 873	13 781	14 879	tonnes	613 547	425 683	382 038	310 483	329 531
7	Inter-city	Private	Auto	Diesel	tonnes	236	351	862	1 640	2 337	tonnes	424	624	1 474	2 632	3 947
8	Inter-city	Private	Light truck	Gasoline	tonnes	1 353	1 394	1 600	1 838	2 115	tonnes	99 850	71 265	66 867	58 628	63 518
9	Inter-city	Private	Light truck	Diesel	tonnes	73	78	89	102	117	tonnes	131	138	152	168	190
10	Inter-city	General freight	Truck	Gasoline	tonnes	163	168	190	224	256	tonnes	14 676	8 631	7 387	5 865	6 150
11	Inter-city	General freight	Truck	Diesel	tonnes	2 835	3 025	3 840	4 872	6 591	tonnes	23 765	21 851	26 210	31 330	35 684
12	Inter-city	General freight	Rail	Diesel	tonnes	1 140	1 137	1 278	1 418	1 547	tonnes	8 445	8 428	9 473	10 507	11 465
13	Inter-city	General freight	Marine	Diesel	tonnes	162	198	256	289	342	tonnes	1 332	1 434	1 876	2 181	2 508
14	Inter-city	General freight	Marine	Heavy FO	tonnes	170	170	158	180	222	tonnes	0	0	0	0	0
15	Inter-city	General freight	Marine	Light FO	tonnes	0	0	0	0	0	tonnes	0	0	0	0	0
16	Inter-city	General freight	Marine	Kerosene	tonnes	0	0	0	0	0	tonnes	0	0	0	0	0
17	Inter-city	General freight	Marine	Coal	tonnes	0	0	0	0	0	tonnes	0	0	0	0	0
18	Inter-city	Specific freight	Rail	Diesel	tonnes	435	442	465	515	563	tonnes	3 227	3 272	3 446	3 814	4 084
19	Inter-city	Specific freight	Marine	Diesel	tonnes	342	365	412	429	450	tonnes	2 508	2 675	3 023	3 141	3 301
20	Inter-city	Specific freight	Marine	Heavy FO	tonnes	0	0	0	0	0	tonnes	0	0	0	0	0
21	Inter-city	Specific freight	Marine	Light FO	tonnes	0	0	0	0	0	tonnes	0	0	0	0	0
22	Inter-city	Specific freight	Marine	Kerosene	tonnes	0	0	0	0	0	tonnes	0	0	0	0	0
23	Inter-city	Specific freight	Marine	Coal	tonnes	0	0	0	0	0	tonnes	0	0	0	0	0
24	Urban	Public	Streetcar&Subway	Electricity	tonnes	0	0	0	0	0	tonnes	0	0	0	0	0
25	Urban	Public	GO-Train	Diesel	tonnes	75	76	82	86	90	tonnes	504	566	608	636	666
26	Urban	Public	Bus	Diesel	tonnes	563	584	654	700	775	tonnes	4 716	4 221	4 468	4 580	4 850
27	Urban	Public	Bus	Gasoline	tonnes	4	4	5	5	6	tonnes	370	226	182	141	142
28	Urban	Private passenger	Auto	Electricity	tonnes	0	0	0	0	0	tonnes	0	0	0	0	0
29	Urban	Private passenger	Auto	Diesel	tonnes	135	202	484	815	1 332	tonnes	243	359	645	1 508	2 230
30	Urban	Private passenger	Auto	Gasoline	tonnes	14 446	15 681	17 310	18 423	19 849	tonnes	630 038	577 447	513 682	415 065	436 667
31	Urban	Private passenger	Light truck	Gasoline	tonnes	1 281	1 338	1 538	1 766	2 033	tonnes	94 632	68 470	64 305	57 290	62 948
32	Urban	Private passenger	Light truck	Diesel	tonnes	59	75	86	98	113	tonnes	106	132	146	161	180
33	Urban	Non freight	Truck	Gasoline	tonnes	1 632	1 710	1 766	1 787	1 712	tonnes	130 332	94 025	78 771	62 652	57 312
34	Urban	Non freight	Truck	Diesel	tonnes	119	150	242	321	380	tonnes	214	266	414	529	641
35	Urban	Freight	Truck	Gasoline	tonnes	63	61	65	60	52	tonnes	5 640	3 324	2 513	1 574	1 257
36	Urban	Freight	Truck	Diesel	tonnes	304	320	384	434	480	tonnes	2 548	2 314	2 484	2 703	3 185
37	Aviation	General	Airplane	Turbo	tonnes	3	3	4	4	5	tonnes	123	126	145	156	175
38	Aviation	General	Airplane	Aviation gas	tonnes	6	6	7	8	9	tonnes	232	238	274	295	332
39	Aviation	Government	Airplane	Turbo	tonnes	14	15	17	18	21	tonnes	504	568	653	704	762
40	Aviation	Government	Airplane	Aviation gas	tonnes	0	0	0	0	0	tonnes	0	0	0	0	0
41	Other	Private	Motorcycle	Gasoline	tonnes	133	142	168	184	227	tonnes	7 545	5 213	4 817	4 370	4 895
42	Other	Other	School bus	Gasoline	tonnes	90	90	90	84	92	tonnes	8 925	5 052	3 738	2 475	2 222
43	Other	Private	Leisure vehicle	Gasoline	tonnes	267	391	457	535	626	tonnes	20 281	21 564	20 652	18 761	20 065
	TOTAL				0	37 829	40 520	46 281	51 695	57 391	0 0	1 695 707	1 344 440	1 218 153	1 019 012	1 078 096

APPENDIX III: MODAL SWITCH (TO RAIL) SUMMARY

The following pages contain a lengthy rationale for reducing carbon fuel combusion and formation of CO_2 and other polluting emissions. There are many presumptions and assumptions leading to conclusions therein awaiting the test of reasonableness of informed readers and critics.

Notwithstanding all that, those conclusions are summarized as follows:

Action/Impact	Goods Transport (2005)	Passenger Transport (2005)
Traffic Diverted	26% of Intercity diesel powered general freight truck transport net tonnes (1.14 X 10^{10} net tonne km/annum diverted to rail (diesel)	80% of rail pass. km/a 50% of intercity diesel bus p.km/a 70% of intra air p.km/a 30% of intercity, gasoline auto p.km/a or 37% of total of those to electric TGV type trains or equivalent.
Petroleum products saved	365 x 10^6 litres diesel fuel/year	762 x 10^6 litres total of aero, auto gasoline and diesel fuel/a.
CO_2 Reduction	1 x 10^6 metric tonnes/a or 7.9% of 20 year annual increase	917,000 Mt/annum net reduction or 7.2% of 20 year annual increase
SO_2 Change	Reduced by 2850 metric tonnes/annum	Net increase of 540 M.T/a based on 25% modern coal source for energy - net decrease of about 534 M.T/a if gas fired gas turbine cycle plant power used
NO_x Reduction	6726 Mt/a	7097 MT/a, less 188 Mt/a or 6909 Mt/a net reduction/a
VOC's Reduction	1596 Mt/a	7194 Mt/a avoided; less power plant
Particulate Reduction	1254 Mt/a	2355 MT/a avoided but very large solid wastes from coal fired station - none if a gas fueled gas turbine cycle.
CO Reduction	7980 Mt/a	58,852 Mt/a avoided electric power station output likely to be very small
TOTAL	20,406 Mt/a (excluding CO_2)	
Federal Excise Tax	$14,581,000/a lost	$30,480,000/a lost (G.S.T. gain on electricity sales value unknown)
Provincial Sales Tax	$16,404,000/a lost	$85,990,000/a lost on fuel tax (sales tax gain on electricity sales value unknown)
Other Factors Provincial Capital Spending	Reduction in road spending capital and maintenance	Same

Oil Supply	Total fuel savings converted to barrels of crude oil total an amount 2 to 3 times daily output of projected Hibernia development	
Impact on Receiver	11.6% increase in rail net tonne km. Likely will trigger capital spending	Requires a new Rail System
Incentive	Rebate of RR provincial fuel tax for shifted traffic - $2,705,000/a	Evaluate costs of not doing so

GOODS AND PASSENGER TRANSPORT

Referring to the March 14, 1991 report of VHB Research and Consulting Inc., "Establishing the Baseline" from page B5 one can see the "Demand" for transportation over the years 1985 to 2005 rising from 3.23×10^{11} to 4.94×10^{11} net units or a rise of almost 53%. During this period, the corresponding rise in energy consumption is shown to rise from 6.15 MJ/a $\times 10^{11}$ to 7.94 MJ/a $\times 10^{11}$ or 29%. Implicit in this is a growing average efficiency of fuel use eg. fewer MJ per net tonne.km or per passenger.km. That is gratifying in terms of satisfying the "vision" but it is not enough to very significantly slow the course to the heralded environmental disaster of global warming consequent to vastly excessive CO_2 production (. . and other greenhouse gas culprits) and that in turn is seen to arise from vastly excessive use of fossil fuels. With minor exceptions (eg. subways etc using their share of nuclear and hydraulic power) all of transport in Ontario (and Canada) is fossil fuel driven.

To reduce the use of fossil fuels one can turn to:

(a) Relying on improvement of specific efficiency in each mode. For example, VHB projects a decrease in MJ/net tonne.km of diesel truck transport from 1.817 to 1.441 between 1985 and 2005, a drop of 21%. For rail general freight, it projects a drop from .242 to .204 or 16%. (All this is included in the aforementioned 29% drop in energy consumption.)

(b) One can seek to switch use of modes. For example, if one were to switch one tonne of freight from truck to rail in 1985, one would reduce energy use rate from 1.817 MJ/km to 0242 MJ/km i.e. by 86%! If the switch occurred in the year 2005, the reduction would be from 1.441 to ,204 MJ/km for each net tonne of movement or 86% also.

If all transport were eligible for such an 86% reduction . . . and one must interject to say it isn't . . . then that 29% rise in annual energy use would be offset by an 86% decrease for a sizeable **net** decrease in consequent CO_2 and other emission production.

When one sees that significant 86% reduction one is seeing the difference in resistance to motion of the constantly flexing low elasticity energy absorbing pneumatic tire used by all highway vehicles versus a still flexing but high elasticity energy-denying steel wheel on a steel rail. The ratio may be as high as 9/1 per unit of gross weight. This ratio decreases as the comparison shifts to units of net weight (i.e. payload) and factors such as tire construction, inflation pressure, rail shell flange friction, wind drag etc are taken into account. In its statement to the task force on May 30, 1991, a CNR representative gave the ratio a more conservative value of 65 to 75% less fuel for rail vs road transport per net load unit weight. Acknowledging that there appears to be this difference between the VHB report values and the CNR values, these comments will continue on the basis of using the VHB values with the expectation that any action proposals resulting from this will be subject to technical verification and/or correction. That difference may lie in accounting for idling fuel, work train fuel etc out of a single massive total.

Since the VHB report can be inferred as incorporating technology improvements in each mode so as to improve efficiency and reduce emissions, then attention can turn here to what might be achieved by nodal switch. This will be discussed separately for "Goods Movement" and for "Passenger Movement".

Goods Movement:

The VHB "base case scenario" date divides transport into 43 different categories based on mode

- zone of operation - urban, interurban etc.
- fuel
- private vs public carrier
- ownership

and so on.

To work into the goods movement potential, three lines 11, 12 and 13 of the VHB tables were selected. These cover general freight powered by diesels on the road, rail and marine modes. Their energy, usage and emission data is provided on table (a) herewith. There are other significant lines: 8 and 9 for private light truck intercity gas and diesel fueled freight plus line 10 for gasoline powered inter city general freight. The discussion will come back to them but line 11, 12 and 13 being all diesel (steam on the way out for years in lake freight) they probably are the most likely representation of rail and road transport competing in a single long haul market and therefore the "figures" likely to change in a market driven modal switch. (How to provide that "drive" is of course another aspect of this whole matter.)

For another reason as well, it seems prudent to look at only these lines first. That is the trend in rail freight operation is to hew mostly to line haul business and to eschew local branch and low volume switching service. That "lost" business is probably part of the growth content of VHB's urban freight where the gasoline (line 35) and diesel (line 36) have 20 year energy growth ratios of **637%** and **41%** respectively. They have a widened collector and delivery market where high power diesel drives are not heavily represented.

As for marine general freight, the growth shown seems surprising. General freight cargo within the Great Lakes System enjoyed bullish ship investment in the 50's only to see this join the scrap yards in the 70's and 80's. Pending stakeholder comment, this is seen to represent alternate bulk cargo aboard bulk carriers . . . cement, salt, limestone, coal, ore, grain etc. None of these are time sensitive and are unlikely candidates for modal switch. Markets for some may move to new locations where marine transport is impractical. In that case modal switch will occur out of necessity. Further as can be seen by inspecting the columns of table (a) there is no environmental gain in stimulating a modal switch from marine to truck or rail unless the distances by marine travel are much greater. No cases of this suggest themselves. Perhaps what exists here is a very functionally effective and efficient mix of intermodal operations e.g.

- cement plant to ship to depot to truck
- grain elevator to rail to ship to market etc. etc.

TABLE (a) ENERGY INPUT & EMISSIONS RELEASES PER NET TONNE KM WITH ANNUAL TOTAL ENERGY AND USEAGE

VHB report line #	MODE	LOAD	Energy MJ/net tonne km	CO_2 grams/net tonne km	SO_2 grams/net tonne km	NO_x grams/net tonne km	VOC's grams/net tonne km	Particulates grams/net tonne km	CO grams/net tonne km	Total Energy MJ/a (all x 10^{10})	Total Use net tonne km net annum (all x 10^{10})
1985 11	Diesel Truck	General Freight	1.817	128.43 /70.68	0.27	2.40	0.26	13	1.08	4.11	2.20
12	Diesel Rail	General Freight	242	17.10 /70.68	0.03 /.11	0.35 /1.44	0.03 /0.07	0.02 /0.08	0.14 /0.57	4.00	6.08
13	Diesel Marine	General Freight	213	15.05 /70.68	0.05 /0.21	0.17 /0.80	0.04 /0.18	0.01 /0.05	0.07 /0.34	1.47	1.84
1990 11	Diesel Truck	General Freight	1.763	124.61 /70.68	0.27	1.99	0.19	0.13	0.93	4.15	2.35
12	Diesel Rail	General Freight	237	16.75 /70.68	0.03 /0.11	0.34 /1.44	0.02 /0.07	0.02 /0.08	0.14 /0.57	4.14	6.19
13	Diesel Marine	General Freight	204	14.42 /70.68	0.04 /0.21	0.16 /0.80	0.04 /0.18	0.01 /0.05	0.07 /0.34	1.47	2.06
1995 11	Diesel Truck	General Freight	1.593	112.59 /70.68	0.27	1.46	0.17	0.13	0.88	4.43	2.98
12	Diesel Rail	General Freight	0.225	15.90 /70.68	0.02 /0.11	0.32 /1.44	0.02 /0.07	0.02 /0.08	0.13 /0.57	4.75	7.32
13	Diesel Marine	General Freight	0.185	13.08 /70.68	0.04 /0.21	0.15 /0.80	0.03 /0.18	0.01 /0.05	0.06 /0.34	1.65	2.98
2000 11	Diesel Truck	General Freight	1.515	107.08 /70.68	0.27	0.94	0.16	0.13	0.83	5.07	3.78
12	Diesel Rail	General Freight	0.214	15.12 /70.68	0.02 /0.11	0.31 /1.44	0.01 /0.07	0.02 /0.08	0.12 /0.57	5.73	8.54
13	Diesel Marine	General Freight	0.180	12.72 /70.68	0.04 /0.21	0.14 /0.80	0.03 /0.18	0.01 /0.05	0.06 /0.34	1.83	3.57
2005 11	Diesel Truck	General Freight	1.441	101.85 /70.68	0.27	0.88	0.15	0.13	0.82	5.66	4.34
12	Diesel Rail	General Freight	0.204	144.42 /70.68	0.02 /0.11	0.29 /1.44	0.01 /0.07	0.02 /0.08	0.12 /0.57	6.25	9.80
13	Diesel Marine	General Freight	0.175	12.37 /70.68	0.04 /0.21	0.14 /0.80	0.03 /0.18	0.01 /0.05	0.06 /0.34	1.99	4.19

Note: Numbers /xx are factors to apply to energy to yield pollutant - e.g. 1995 line: 1.593 x 70.68 = 112.59

Return now to lines 11 and 12 of table (a). What would it take to produce a favourable environmental impact and is the implied action practical?

To approach this, one can examine the total CO_2 production of all transport. If all energy for transport in Ontario is 7.94×10^{11} MJ in the year 2005 and if one can generalize by inspection, that all energy converts to say, 70 grams of CO_2 per MJ, then in year 2005 all this transport activity converts to $7.94 \times 10^{11}\ \text{MJ} \times 70\text{g/MJ} \times \frac{1}{10^6\text{g/metric tonne}}$

one finds annual CO_2 to be 55.58×10^6 metric tonnes. In 1985, it is similarly calculated as 43.05×10^6 m.t/a. The 20 year increase is thus 12.53×10^6 mt/a.

If one then looks at lines 11 and 12 of table (a), one sees a decrease of CO_2 production per net tonne.km modal switch road to rail of (128.43-17.10) grams or 111.33 grams/net t.km of switch in 1985 or (101.85-14.42) or 87.43 grams in year 2005.

A million metric tonnes of annual CO_2/gr production seems a worthwhile proposal. It would be 1.8% of **total** transport CO_2 production in 2005, or 7.9% of the annual increase in 2005 over 1985. With a production rate of 87.43g/net t.km would require a shift of

$\frac{1{,}000{,}000\ \text{tonnes/yr}}{87.43\text{g/t.km}} \times \frac{1000\ \text{kg}}{\text{t}} \times \frac{1000\text{g}}{\text{kg}}$ or switch of 11.44×10^9 t.km

or 1.144×10^{16} t.km/year. That's $\frac{1.14}{4.34} \times 100\%$ of the annual projected truck traffic

or

26% of line 11.

If one was to add to line 11, the tonne.km of lines 8 and 9, the other private trucks, gas and diesel plus line 10, the general freight gasoline powered trucking - all intercity - which have these projected year 2005 traffic

Line 8	6.22×10^9 vh.km/yr }	@ say 5 net tonnes/veh	{3.10×10^{10} t.km/a
Line 9	2.61×10^8 " " }		{ $.13 \times 10^{10}$ t.km/a
Line 10	1.22×10^{10} ton.km/yr		1.22×10^{10} t.km/a
		Total (2005)	4.45×10^{10} t.km/a

This almost equals lines 11 plus 12 and brings a total of 4.34 + 4.45 or 8.79t.km/a x 10^{10}.

Thus the 1.14×10^{10} t.km/a of modal switch can also be seen as 13% of the total (8.70×10^{10}) year 2005 truck (private and public, both fuels) inter-urban freight movement.

Is a switch of 1.14×10^{10} t.km/a a reasonable number to contemplate? The trucking industry will likely say "no" with vehemence at the loss of 13 or 26% depending on how one looks at it. The rail industry will likely say "yes" with anticipation of an 11.6% increase in 2005. But one must look beyond who gets and who loses for more substantial appreciation.

If one were to assume for simplicity's sake that all of the truck freight was carried in 42000kg authorized gross weight trucks with tare weight of tractor and trailer of say 14,800kg, the potential net weight is 27,200kg or 27.2 metric tonnes. Not all trucks move at their weight limit. A Ministry of Transport study on "climbing lane" rationale includes results of a limited survey that says they move at 70-100% of allowable weight. If one used the average of 85% then gross weight would be .85 of 42,000kg or 35,700kg and payload would suffer that full reduction of 6,300kg down to 20,900kg or 20.9 metric tonnes. Then reduction of 1.14 x 10^{10} t.km/a by road transport means a reduction of
1.14 x 10^{10} ÷ 20.9 or 54.55 x 10^{10} vehicle km/year. That's 152,192 v.km/day (300 days/yr). At a utilization of 700km/worker day, that's something like an employment loss of 217 driver persons, plus terminal workers etc.

As a rail movement in year 2005, those 1.14 x 10^{10} net tonne.km could move in trailers on flat cars, containers on flat cars one or two high, in regular box cars or in bi-modal Road Railers. They may move then at higher net tonnes/gross tonne ratio, or lower. If one was to assume the same vehicle km/a impact as though all net weight moved in trailers on flat car and that the table (a) data is unaffected by these assumptions then one can further estimate the picture could be

- one half of the 1.14 x 10^{10} net tonne.km occurring on 500km routes and one half on 1000km routes. These correspond very roughly to Montreal/Toronto and Montreal/Windsor. This isn't necessarily realistic but it does start to be indicative. Assume further that the net weight/rail unit is the same 20.9 metric tonnes each.

That gives .57 x 10^{10} net t.km ÷ 20.9 t/unit
or 545,454 load units/year on 500km trips
or 1818 load units/day on 500km trips (300d/yr)
also 909 load units/day on 1000km trips (300d/yr)

A rail system should find it practical to move these in 75 unit trains so that given 24 trainloads total in both directions over 500km i.e. 12 each way plus the 12 train loads total in both directions over 1000km of route, i.e. 6 each way.

If there is a greater variety of routes and distances obviously these concentrations will be reduced.

That represents 24 + 12 or 36 crew member employment 6 days/week or 216 crew member days/week or say 216/5 or 43 crew member incremental employment, plus support portions.

While the road system could unquestionably accommodate a drop of traffic, it's not clear that the rail system could accommodate the traffic increment without new investment and/or without clarification of routes. There's a great deal of unused rail capacity and potential for increasing track capacity but the question is does available capacity match modal switch needs. One could guess it likely does match location-wise at least because it is surplus now largely because of modal switch to truck in the past.

If all this switching could happen without incentive, it would be happening now. it doesn't seem to be happening. The trucking industry proposes the trial use of double 48' trailers under some conditions on Hwy 401 - Montreal/Oshawa. These should save fuel and emissions per ton/km, the exact indications on this are not clear and likewise it's not clear where they would fit within the VHB data. Such trial use would depend on road use policy considerations that are beyond this study. Maybe there's a justifiable niche for these, maybe not. This task force would look for data to compare with the VHB data.

It is fundamental science that a big change will only come with modal switch. Everything else is fine tuning, **all assuming service to shippers can be sustained at the price and the level they expect and require.**

There are other implications and results flowing from a hypothetical reduction of annual CO_2 production (in 2005) and, of course, based on the VHB Base Case Data, one sees.

(a) Diesel and light fuel oil have 38.68 GJ/M^3

That is $38.68 \frac{GJ}{M^3} \times 1000 \frac{MJ}{GJ} \times \frac{1M^3}{10^6CC} \times \frac{1000CC}{Litre}$ or $38.68 \frac{MJ}{L}$

Motor Gasoline, for information has $34.66 \frac{MJ}{Litre}$

(b) The hypothetical modal shift represents an energy use reduction of $(1.441 - 0.204) \frac{MJ}{t.km} \times 1.14 \times 10^{10} \frac{t.km}{yr.}$ or $1.41 \times 10^{10} \frac{MJ}{annum}$

That's $\frac{1.41 \times 10^{10}}{38.68} \frac{Litres}{a}$ or 364.53×10^6 Litres/annum

(c) Along with the 1 million metric tons of CO_2/year reduction in year 2003 or 1.8% of all transport CO_2 there are these effects as well:

- NO_x reduction: $(0.88 - .29)\frac{g}{t.km} \times \frac{1.14 \times 10^{10}\ t.km/a}{10^6 g/Mt}$
or 6726 metric tons/annum

- VOC's reduction $(.15 - .01) \frac{g}{t.km} \times \frac{1.14 \times 10^6\ t.km/a}{10^6\ g/Mt} = 1596\ MT/a$

- Particulates reduction $(.13 - .02)\ g/t.km \times \frac{1.14 \times 10^{10}\ t.km/a}{10^6\ g/Mt} = 1254\ Mt/a$

- CO reduction $(.82 - .12)\ \frac{g}{t.km} \times \frac{1.14 \times 10^{10}\ t.km/a}{10^{6}} = 7980\ Mt/a$

- SO_2 reduction $(.27 - .02)\ \frac{g}{t.km} \times \frac{1.14 \times 10^{6}\ t.km/a}{10^{6}} = 2850\ Mt/a$

Total emissions (other than CO_2) 20,406 Mt/a

(d) Impact on principal government revenues/costs would be as follows:

- net loss of provincial sales tax at 4.5¢/litre (1/1/92) of lost oil sales would be 364.53 X 10^6 X \$.045 or \$16,404,000

- net loss of federal excise tax revenue @ 4¢/litre i.e. \$14,581,000

- a likely net gain of revenue by reduction of deferred tax (provincial and federal) by virtue of reduced investment or fewer high capital cost allowance (i.e CCA) road assets vs more low CCA rail assets

- a significant reduction of Ontario road wear and tear and consequent maintenance costs

- a likely stretchout/deferral/cancellation of road capital improvements for Ontario

- avoidance of cost elsewhere to achieve these emission reductions

As noted earlier, modal switch is not happening on its own merits. The rise in the absolute **difference** between road and rail fuel sales taxes which will have gone from **7.5¢**/L pre budget '91 to **9.8¢**/L as of Jan. 1, 1992 may have some shift effect. No measurement of this is available to the task force. To give the modal switch a nudge, it is suggested that the province rebate the rail fuel tax (4.5¢/Litre as of Jan. 1, 1992) to the railroads for **fuel purchased in Ontario and attributed solely to satisfying modal switch.**

That would amount to:

$$1.14 \times 10^{10}\ \frac{t.km}{a} \times .204\ \frac{MJ}{t.km} \times \frac{1}{38.68\ MJ/L} \times \frac{\$.045}{L}$$

i.e. \$2,705,000/year. That incentive represents \$2.70/metric ton/year. (The coming U.S. trading in emission futures should give some indication whether this is high or low.)

If a railroad used the rebate to give it more competitive price freedom, the amount wouldn't seem to buy much of that. The \$2,705,000 per year for helping gain say 1/2 of the 1.14 X 10^{10} t.km per year is almost immeasurably small. If a railroad sheltered the rebate from income tax by making new investments in say rolling stock, the low Capital Cost Allowance rates in Canada coupled with the first year 50% only rule, would require rather large investments to shelter the rebate. If, for example, it was used for rail cars (7% CCA) then in the first year of a $2,705,000 rebate (assumes all according to corporate tax paying discipline) the investment could be $\frac{\$2,705,000}{.07 \text{ X } 1/2}$ or $77,000,000 approximately. The Ontario Sales Tax component in that is about $5.4 million and the G.S.T. about $4.7 million. This is all pretty wild and extreme investment economics but it's intended to provoke qualitative thinking of what might be.

The road hauler would be gasping if such an incentive were introduced without some guidance on how they as an industry could survive. Obviously if railroads found this very attractive and managed to enlarge market share as hypothesized, some extra trucker drayage would be needed by the railroads but there would be a loss of use for heavy investment in tractors and truck terminals. Perhaps railroads and some truck operators could find a formula for collaboration - e.g. more wholesaling of line haul by truckers to railroads, or, some new kind of joint venture involving say Road Railers (bimodal trailers used directly on road or rail as needed).

Another suggestion would be to devise a system of road hauler taxation that imitates the weight/distance method for the permit or combines that method for both permit and usual weight/distance. A front end deposit credit in respect of the permit amount would be required and any shortfall of mileage would create a rebate credit at the end of 12 months. This could be a way of reducintg trucker exposure while groping with a new intermodal mix.

Passenger Movement

With goods movement, the Marine Mode was left untouched although its growth was viewed sceptically.

In the case of passenger movement, there are still the rail and road modes (with public and private use of the latter) and the air mode. All of these will be involved here.

Consulting the tables of the VHB Base case scenario some severe anaomalies show up.

(a) Line 1 public intercity rail, shows traffic growth but a 20 year steady 1.833 MJ/pass km. One would think that with growth there would be some capture of the freight railroads improving fuel efficiency.

(b) Line 2 public, intercity bus, appears hobbled as in line 1 at a steady 0.869 MJ/p km

(c) Line 4 public "intra air" travel (within Ontario) shows as a steady 4.391 MJ/p km over the 20 year period whereas aero efficiencies are still improving

(d) Line 4 public "extra air" travel (to long distance destinations), shows an unexplainable **6384.4** MJ/p km throughout this high growth period.

Referring to another source: "Energy & Environmental Factors in Intercity Transportation" (Dr. A.M. Kahn - for Transport Canada) one finds some technology specific information. For example, from table 3.2 one finds LRC passenger train (as provides most of the corridor service) consumes various amounts of energy per seat km depending on train size and average speed. Of these speeds, 145 km/hr. is selected as representative of highest averages in the corridor. With an 'average' of 280 seats (5 cars) the resultant energy use is .527 MJ/seat km. This must be grossed up according to load factor.

In his table 3.3 heavy full service (baggage cars, sleepers, dining cars etc.) long distance trains have almost 3 times the energy consumption per seat km.

None of the VHB data covers electric high speed train performance. To take a cut at this, reference is made to the GEC/Alsthorm TGV promotional material for the latest TGV Atlantique information. It has been advertised (Fin. Post - July 20) as offering 2 1/2 hour service Toronto to Montreal. (via Ottawa presumably) i.e. about 570 km (via Ottawa). It has installed power of 8800 kw for traction and by assumption, another 1,000 km of auxiliary load. Each train set can carry "over 500 passengers". In 2 1/2 hours, the drive system will use 8800 kw's (2.5 hours less coasting, braking and stop time) - say 17,600 KWH. PLUS 2 1/2 hrs. X 1000 kw or a total of 20,000 KWH. That's 20,100 X 3.6 MJ/kWh or 72,360 MJ/trip or $\frac{72,360\text{MJ}}{500 \text{ X } 570}$ or 0.254 MJ/seat km.

All this must be grossed up by the electrical efficiency (about 90%) or .282MJ/seat km and by load factor to get pass. km info. It must be factored down for CO_2 and emissions by the proportion of hydro and/or nuclear in the supply. Then, of course, there is the hazard of such a rough calculation.

Intercity bus fuel consumption shown in table 3.6 shows an improvement beyond year 2000 from 317 kj/seat km. prior.

Like in goods movement these Transport Canada report numbers may rationalize after taking into account differences in speed and hence wind resistance. The big difference in specific energy consumption comes when air is compared to rail or bus (road). The Transport Canada report shows a B737 108 seat aircraft working out to 1.30 MJ/seat km at cruising speed. Not all planes are B737's but it's a natural fit for much of Ontario corridor flying. Much better efficiency - .738 MJ/seat km shows up for a slower cruising dash 8 but these account for many fewer passenger km than a B737. A larger B767 shows up at 1.205 MJ/seat km.

Then there is the automobile. The VHB tables show the intercity useage as gasoline powered to be 8 times (only !?) that of diesel powered autos and registering 3.093 MJ/Veh.km (gasoline) in 1985 dropping to 2.663 in year 2005. The diesel powered auto drops from 1.304 to 1.073 in that period. Obviously the key to this will be passengers per vehicle.

For urban service the specific energy useage is higher, of course. 4,585 MJ/Veh.km down to 3.996 by 2005. By contrast the urban diesel bus only shows up at a steady 2.109 MJ/pass.km. With 2 passengers/auto, the energy quotient is a virtual standoff here. Electric rail (city) transportation in the city uses about .45 MJ/pass.km and seems unbeatable except by massive car pooling.

It will be obvious to the reader, especially with the referenced reports in hand, that there is a glimmer of potential energy. CO_2 and emission savings in modal switching. Putting all this in some kind of ranking we see for intercity service:

(i) air/avg. @ 4.391 MJ/p.km steady, per VHB
(ii) auto/gas @ 2.663 MJ/Veh.km, year 2005, per VHB
(iii) air/B737 @ 1.30 MJ/seat km, current, per Transport Canada
(iv) rail/LRC @ .527 MJ/seat km, current, per Transport Canadaor rail avg. @ 1.739 MJ/pass. km, steady, per VHB
(v) bus avg. @ .869 MJ/pass.km, steady, per VHB or bus @ .317 MJ/seat km, beyond year 2000 per Transport Canada
(vi) rail/TGV @ ≈ .282 MJ/seat km calculated or @ ≈ .07 MJ/seat km if only 25% fossil generation

Again, subject to verification of (vi) above, there is an apparent overwhelming environmental case for modal switch to electric high speed trains! Putting a 20% accuracy penalty on the .07 MJ/seat km to raise it .084 MJ/seat km then going on to assume

(a) 80% load factor on (iii) or 1.625 MJ/pass. km
(b) 2 passengers per intercity auto (ii) of 1.332 MJ/pass.km
(c) 80% load factor on bus (v) alt. or .40 MJ/pass.km
(d) 60% load factor on Rail LRC or .66 MJ/pass.km
(e) 70% load factor on (vi) TGV after source correction and accuracy penalty, i.e. .084 ÷ .7 or .12 MJ/pass km

one can start calculations of "what if".

In the goods movement section a cut of one million metric tons of CO_2/annum in year 2005 represented only 7.9% of the increase of CO_2/annum in 2005 vs 1985 and 1.8% of the year 2005 total. In terms of vision targeting of much much larger reductions there must be much bolder action.

Returning to the VHB data one sees for the year 2005:

Line 1 rail travel2.06 X 10^9 pass.km/annum
Line 2 bus travel2.08 X 10^9 pass.km/annum
Line 4 air (intra)6.05 X 10^9 pass.km/annum

Line 6 auto (gas) $\underline{44.10 \times 10^9}$ pass.km/annum
Total 54.29×10^9 pass.km/annum

Assume (!)

- 80% of rail useage can be switched to electric rail, i.e. 1.648×10^9 pass km/a
- 50% of bus useage can be switched to electric rail, i.e. 1.04 " "
- 70% of air useage can be switched to electric rail, i.e. 4.235 " "
- 30% of auto useage can be switched to electric rail, i.e. $\underline{13.230}$ " "

20.153 " "

i.e. a total switch of 20.153 X 10^9 pass.km/yr. or
37% --- not unreasonable.

Consequential energy and CO_2 savings

(a) From air $4.235 \times 10^9 \ \frac{\text{pass.km}}{\text{a}} \times (1.625 - .12)\ \frac{\text{MJ}}{\text{p.km}} = 6.37 \times 10^9\ \frac{\text{MJ}}{\text{a}}$

(b) From auto $13.23 \times 10^9 \ \frac{\text{pass.km}}{\text{a}} \times (1.532 - .12)\ \frac{\text{MJ}}{\text{p.km}} = 18.68 \times 10^9\ \frac{\text{MJ}}{\text{a}}$

(c) From bus $1.04 \times 10^9 \ \frac{\text{pass.km}}{\text{a}} \times (.40 - .12)\ \frac{\text{MJ}}{\text{p.km}} = .92 \times 10^9\ \frac{\text{MJ}}{\text{a}}$

(d) From rail $1.648 \times 10^9 \ \frac{\text{pass.km}}{\text{a}} \times (.66 - .12)\ \frac{\text{MJ}}{\text{p.km}} = .89 \times 10^9\ \frac{\text{MJ}}{\text{a}}$

This totals 26.86×10^9 MJ/annum or $2.686 \times 10^{10}\ \frac{\text{MJ}}{\text{a}}$

This compares to the $1.41 \times 10^{10}\ \frac{\text{MJ}}{\text{a}}$ saved in the goods switch or almost 2 X that saving.

All of the energy saved is from refined petroleum. All of the **fossil** energy included in the TGV electric train energy source (25%) is assumed to be coal. It will have slightly higher CO_2/MJ than the petroleum fuels because of the near absence of hydrogen in the coal **and** it will produce some SO_2 which gasoline and aero engine fuels do not.

As with goods movement, assume that the CO_2 production is flat at a 70 grams/MJ. This results in a saving of $26.86 \times \frac{10^9}{\text{MJ}} \times \frac{70\,\underline{\text{g}}}{10^6} \times \underline{1}\,\text{g/MJ}$ or

1.88 million metric tons of CO_2.

However, the electric power plant will produce CO_2 at 860 grams (Hydro Plan) per KWH or a total of

$$20{,}153\ \frac{\text{pkm}}{\text{yr.}} \times 10^9 \times .12\ \frac{\text{MJ}}{\text{p.km}} \times \frac{1}{3.6\text{MJ/kWh}} \times 860\text{g/kWh} \times \frac{1}{10^6} \times \frac{\text{M.T}}{\text{g}}$$

or 963,000 MT/a. That's still a net reduction of 917,000 Mt/a of CO_2.

The change in SO_2 production would be: (none produced by auto or air)

Deduct:

For bus (per VHB) $$.40\ \frac{\text{g}}{\text{p.km}} \times 1.04 \times 10^9 \frac{\text{p.km}}{\text{a}} \times \frac{1}{10^6/\text{MT}}$$

or 416 metric tonnes/year

For rail (per VHB) $$.11\ \frac{\text{g}}{\text{MJ}} \times .66\ \frac{\text{MJ}}{\text{p.km}} \times 1.648 \times 10^9\ \frac{\text{p.km}}{\text{a}} \times \frac{1}{10^6\text{g/Mt}}$$

or 118 metric tonnes/year

Total deducted - 534 metric tonnes/year

Add From electric energy source.

$$\frac{20.153 \times 10^9}{10^6\ \text{g/mt}}\ \frac{\text{pass.km/yr.}}{} \times .12\ \frac{\text{MJ}}{\text{pass.km}} \times \frac{1}{3.6\ \text{MJ/KWH}} \times 1.60^*\ \frac{\text{g}}{\text{KWH}}$$

or 1074 metric tons/year

Net Change: 1074 - 534 or 540 metric tons/year increase. (Note: goods transport switch reduced SO_2 by 2850 metric tons/annum.)

Note: If the electric supply fossil fuel energy component were to be from gas fired gas turbines with bolloming steam cycles the SO_2 addition would be negligible and there would be a net reduction of about the 534M tonnes.

* Hydro - Demand Supply Plan - P.14-29'

Other Pollutants:

NOx- Deduct from air: @ .03 grams/MJ

i.e. $$4.235 \times 10^9\frac{\text{p.km}}{\text{a}} \times 1.625\ \frac{\text{MJ}}{\text{p.km}} \times .03\ \frac{\text{g}^*}{\text{MJ}} \times \frac{1}{10^6}\ \frac{\text{MT}}{\text{g}}$$

or 219 MT/a

- Deduct from auto:

$$13.23 \times 10^9 \frac{\text{p.km}}{\text{a}} \times 0.3 \frac{\text{g}^*}{\text{p.km}} \times \frac{1}{10^6} \frac{\text{MT}}{\text{g}}$$

or 3969 MT/a

- Deduct from bus:

$$1.04 \times 10^9 \frac{\text{p.km}}{\text{a}} \times 1.30 \frac{\text{g}^*}{\text{p.km}} \times \frac{1}{10^6} \frac{\text{MT}}{\text{g}}$$

or 1352 MT/a

- Deduct from rail:

$$1.648 \times 10^9 \frac{\text{p.km}}{\text{a}} \times .66 \frac{\text{MJ}}{\text{p.km}} \times \frac{1.44\text{g}^*}{\text{MJ}} \times \frac{1}{10^6} \frac{\text{MT}}{\text{g}}$$

or 1566 MT/a

Total NO_x avoided 7,097 MT/a

* These factors are from VHB table B5 year 2005, with the auto factor halved to convert from vehicle km to passenger km using 2 persons/vehicle. (assumption)

NO_x produced by the power system is taken as .28g/KWHr (see Hydro Plan P. 14.29) Thus for an electric rail system of 20.153×10^9 pass.$\frac{\text{km.}}{\text{yr.}}$ and $.12 \frac{\text{MJ}}{\text{p.km}} \times \frac{1}{3.6\text{MJ/kWh}} \times \frac{28\text{g}}{\text{kWh}}$

$\times \frac{1}{10^{6\text{g/mt}}}$, one gets $188 \frac{\text{MT}}{\text{yr.}}$

VOC's

- Deduct from air:

$$4.235 \times 10^9 3 \frac{\text{p.km}}{\text{a}} \times 1.625 \frac{\text{MJ}}{\text{p.km}} \times .04 \frac{\text{g}^*}{\text{MJ}} \times \frac{1}{10^6} \frac{\text{MT}}{\text{g}}$$

or 275 Metric tonnes annum

- Deduct from auto:

$$13.23 \times 10^9 \frac{\text{p.km}}{\text{a}} \times .50 \frac{\text{g}^*}{\text{p.km}} \times \frac{1}{10^6} \frac{\text{MT}}{\text{g}}$$

or 6615 MT/a

- Deduct from bus:

$$1.04 \text{ X } 10^9 \frac{\text{p.km}}{\text{a}} \text{ X } .22 \frac{\text{g}^*}{\text{p.km}} \text{ X } \frac{1}{10^6} \frac{\text{MT}}{\text{g}}$$

or 228 MT/a

- Deduct from rail:

$$1.648 \text{ X } 10^9 \frac{\text{p.km}}{\text{a}} \text{ X } .66 \frac{\text{MJ}}{\text{p.km}} \text{ X } .07 \frac{\text{g}^*}{\text{MJ}} \text{ X} \frac{1}{10^6} \frac{\text{MT}}{\text{g}}$$

or 76 MT/a

Total VOC's avoided 7194 MT/a.

Particulates

- Deduct from air - zero

- Deduct from auto: .17g*/p.km, i.e.

$$13.23 \text{ X } 10^9 \frac{\text{p.km}}{\text{a}} \text{ X}.17 \frac{\text{g}}{\text{p.km}} \text{ X } \frac{1}{10^6} \text{ or } 2249 \frac{\text{MT}}{\text{a}}$$

- Deduct from bus: .19g*/p.km

$$1.04 \text{ X } 10^9 \frac{\text{p.km}}{\text{a}} \text{ X}.19 \frac{\text{g}}{\text{p.km}} \text{ X } \frac{1}{10^6} \text{ or } 198 \text{ MT/a}$$

- Deduct from rail: .08g/MJ

$$1.648 \text{ X } 10^9 \frac{\text{p.km}}{\text{a}} \text{ X } .66 \frac{\text{MJ}}{\text{p.km}} \text{ X } .08 \frac{\text{g}}{\text{MJ}} \text{ X } \frac{1}{10^6} \text{ or } 87 \text{ MT/a}$$

Total avoided particulates 2355 MT/a

The same electric power plant would produce 95g/KWH, (Hydro Plan)

$$\text{i.e., } 20.153 \text{ X } 109 \frac{\text{p.km}}{\text{yr.}} \text{ X } .12 \frac{\text{MJ}}{\text{p.km}} \text{ X } \frac{1}{3.6\text{MJ/KWH}} \text{ X } \frac{95\text{g}}{\text{KWH}} \text{ X } \frac{1}{10^6} \frac{\text{MT}}{\text{g}}$$

or 53,182 metric tonnes of "solid wastes"/year. This is presumed to mean stack wastes **not** caught by precipitators or other means.

CO

- Deduct from air: .11g*/MJ

$$\text{or} \quad 4.235 \ \text{X} \ 10^9 \ \frac{\text{p.km}}{\text{a}} \ \text{X} \ .11\frac{\text{g}}{\text{MJ}} \ \text{X} \ 1/10^6 \quad \text{or} \quad 7570 \ \text{MT/a}$$

- Deduct from auto: 3.74g*/p.km

$$\text{or} \quad 13.23 \ \text{X} \ 10^9 \ \frac{\text{p.km}}{\text{a}} \ \text{X} \ \frac{3.74 \ \text{g}}{\text{p.km}} \ \text{X} \ \frac{1}{10^6} \quad \text{or} \quad 49{,}480 \ \text{MT/a}$$

- Deduct from bus: 1.21 g/p.km

$$\text{or} \quad 1.04 \ \text{X} \ 10^9 \ \frac{\text{p.km}}{\text{a}} \ \text{X} \ 1.21 \frac{\text{g}}{\text{p.km}} \ \text{X} \ 1/10^6 \quad \text{or} \quad 1258 \ \text{MT/a}$$

- Deduct from rail: 0.57 g/MJ

$$\text{or} \quad 1.648 \ \text{X} \ 10^9 \ \frac{\text{p.km}}{\text{a}} \ \text{X} \ .57 \frac{\text{g}}{\text{MJ}} \ \text{X} \ \frac{1}{10^6} \quad \text{or} \quad 544 \ \text{MT/a}$$

Total CO avoided 58,842 MT/a

Electric power plant CO plant production unknown - likely less than "avoided".

Liquid Fuel Consumption Decrease

a)From air $6.37 \ \text{X} \ 10^9 \frac{\text{MJ}}{\text{a}} \ \text{X} \ \frac{1}{35.93\text{MJ/L}}$ or $177 \ \text{X} \ 10^6$ Litres/annum

b)From auto $18.68 \ \text{X} \ 10^9 \frac{\text{MJ}}{\text{a}} \ \text{X} \ \frac{1}{34.66\text{MJ/L}}$ or $538 \ \text{X} \ 10^6$ Litres/annum

c)From bus $.92 \ \text{X} \ 10^9 \frac{\text{MJ}}{\text{a}} \ \text{X} \ \frac{1}{38.63\text{MJ/L}}$ or $24 \ \text{X} \ 10^6$ Litres/annum

d)From rail $.89 \ \text{X} \ 10^9 \frac{\text{MJ}}{\text{a}} \ \text{X} \ \frac{1}{38.63\text{MJ/L}}$ or $23 \ \text{X} \ 10^6$ Litres/annum

TOTAL VOLUME $762 \ \text{X} \ 10^6$ Litres/annum

Government Revenue Impact

Federal Excise Tax Lost 762 X 10^6 X \$.04 = \$30.48 X 10^6/yr.

Provincial Sales Tax Lost

From air	177 X 10^6 X \$.027	or	\$4.78 X 10^6/yr.
From auto	538 X 10^6 X \$.147	or	\$79.07 X 10^6/yr.
From bus	24 X 10^6 X \$.045	or	\$1.08 X 10^6/yr.
From rail	23 X 10^6 X \$.045	or	\$1.04 X 10^6/yr.
TOTAL			\$85.99 X 10^6/yr.

Gains from tax on electricity sales --- depends on electricity price. Benefits both levels.

APPENDIX IV: SWITCH FROM DIESEL TO ELECTRIC BUS

SUMMARY

This looks principally at switching a dense metropolitan area diesel bus system to electric buses powered from gas fired gas turbines in combined cycle. It also references CNG buses. Using a base of 1.0 X 10^8 vehicle Km/a or about 90% or so of the likely diesel bus operation in Toronto, Mississauga and Hamilton, it shows reductions from a 1989 diesel base of:

$C0_2$: 48,200 MT/annum (MT = Metric Tonnes)
$S0_2$: something approaching 364 MT/a of diesel
$N0_x$: 2728 MT/annum
VOCs : 272 MT/annum
Parts : something approaching 180 MT/a of diesel
C0 : 1107 MT/annum

A CNG bus would not do as well. If LRT were eligible to receive some of this traffic, savings would be greater.

I A LOOK AT URBAN BUSES

a) The VHB Report Base Case Scenario (table B4), line 26, lists the urban bus as consuming 2.109 MJ/pass.km, flat, from 1985 to 2005.

b) In its report AT-91-01, MTO's "Assessment of Transit Bus Propulsion Option in Ontario" lists TTC's average diesel bus fuel consumption as 5.4 miles per Imperial gallon. That's $\frac{5.4}{.62137}$ km/gal. or 8.69 km/gal.

c) Each gallon has 175.84 MJ; therefore this represents 20.23 MJ/veh.km.

d) In 1989, TTC logged 60,937 X 10^3 bus miles. That's $\frac{60,937}{.62137}$ X 10^3 bus kms or 98,068,783 bus km.

e) If all these numbers have some coincidence, then at 2.109 MJ/pass.km and 20.23 MJ/veh.km, TTC carried an average of 20.23/2.109 pass/vehicle or 9.6 pass/vehicle.

f) The total diesel bus fuel consumption of TTC in 1989 (assumes no gasoline buses) would be 98.069 X 10^6 bus kms. X 20.23 MJ/veh.km. or 1.984 X 10^9 MJ/yr.

g) The total diesel urban bus fuel consumption projected by VHB for Ontario is given as:

1985	-	6.27 X 10^9 MJ/a	
1990	-	6.51 X 10^9 MJ/a	- TTC's 1989 total is 30.5% of this
1995	-	7.29 X 10^9 MJ/a	
2000	-	7.90 X 10^9 MJ/a	
2005	-	8.64 X 10^9 MJ/a	
Growth		38% over 20 years	

h) The total urban bus diesel fuel use projection for 2005 of 8.64 X 10^9 MJ/a is just a bit more than the total of diesel truck and rail inter urban general freight, i.e. (6.25 + 1.99) X 10^9 or 8.24 X 10^9 MJ/a.

i) The MTO has led a development program in collaboration with several municipal transit systems (Toronto, Hamilton, Mississauga) and with manufacturers. The MTO reports (page 42, report #AT91-01) that at TTC, the average natural gas vehicle fuel consumption converted to (heat equivalent) diesel equivalent was 4.3 veh. miles/imp. gal.

At $38.68\,\frac{\text{MJ}}{\text{litre}}$ or $175.84\,\frac{\text{MJ}}{\text{1 gal.}}$ and .62137 km/mile, that all works out to

$\frac{175.84\ \text{MJ}}{4.3/.62137\ \text{veh.km}}$ or 25.41 MJ/veh.km

These test vehicles may (or may not) have had an average load of more than 9.6 passengers. At 25.41MJ/veh.km versus current diesel (same MTO report) of 20.23MJ/veh.km suggests that the natural gas bus may be a higher producer of CO_2 per vehicle km. This must await more development and testing to come to any such conclusion. The high content of hydrogen in the natural gas, compared to carbon, would be a factor favouring less CO_2, as well.

On an energy cost basis, and using data from P82 of the MTO report AT91-01, table 34, it can be seen (after conversion) that gas at 35.86¢/MJ (no tax) and diesel in 1989 at 95¢/Mj or "future diesel" at $1.18/MJ, (both taxed), the use of natural gas as a fuel has strong attraction vastly exceeding the $\frac{25.41}{20.23}$ or 5 to 4 ratio of use. Strategically, the use of natural gas has much to commend it as well.

(j) One should bear in mind, though, that natural gas in buses must first be compressed from distributor pressure level of 15-20 or 50 psig, to in excess of 3000 psig to provide a reservoir to fill bus tanks to 3000 psig. This is a substantial energy usage. It is acknowledged and used in the findings of the Hamilton Street Railways' current study of alternatives. (Transport 2000 Ontario found the electric motor driven compressor electric energy to be up to 16% of the energy required to run a trolley coach the same distance as a 90% fill on each gas bus would do. Details provided in a T2000 Ontario report to TTC in January 1991.)

II A LOOK AT ENERGY CONVERSION AND USAGE

(a) So far we've seen:

- Diesel buses (1989) averaging 20.23MJ/veh.km (I(f))
- Gas buses (early results) averaging 25.41MJ/veh.km
- About 30% of Ontario's urban bus diesel fuel is used by TTC. Add in Mississauga and Hamilton and that should rise by about 5 percentage points as at least a guesstimate. (Population ratio is about 15-20% of TTC area.)

(b) Also, there is a vast and growing use of high efficiency combined cycle gas and steam turbine gas fuel power generating systems available to electric utilities. (See write up Electricity - more from less.) Depending on size, design (i.e. manufacturer) these run at 50% +/- 2 points or so of efficiency - Assume 48% for further analysis. That is, for each kWhr (i.e. 3.6MJ) of send out energy, $\frac{3.6\text{MJ}}{.48}$ or 7.5MJ must be consumed. This assumes running as part of a large system, at full load.

(c) If such energy were directed to electric buses, there would be 5 to 10% loss in the electric transmission system between generation and substation. Normally one wouldn't expect as low as 5% but it is assumed the generation would be located close to the city **and** to a "tap" on a high pressure gas pipeline to provide adequate fuel gas injection pressure for the gas turbine.

(d) Taking an average of 7.5% losses, i.e. 92.5% efficiency, the fuel input to produce one kWh rises from 7.5MJ to $\frac{7.5}{.925}$ or 8.1MJ/kWhr.

(e) In that MTO report (table 35, page 82) there is shown an energy consumption rate of 2.92 kWh/veh.km which is understood to be that of a TTC owned fleet. There are grounds to believe this would be 20 to 30% less (say 25%) with a fleet of modern inverter/AC drive systems instead of TTC's 40+ year old resistance/cam control systems. That would mean an average of 2.92 x .75 or 2.19kWhr/veh.km. The larger the electric vehicle network, the more receptive it would be to regenerative braking, thus assuring maximum efficiency.

(f) On the basis of 2.19kWhr/veh.km and 8.11MJ/kWhr for generating those kWhrs with natural gas, the gas fuel used per electric T.C. vehicle km becomes 8.11 x 2.19 or 17.76MJ/veh.km.

(g) It will be obvious to the reader that 17.76MJ/veh.km and the 25.41MJ/veh.km (excluding compression) for the natural gas bus need a little more verification that that provided in this report. **However**, where a concentration of 35% or so of Ontario's urban bus diesel fuel is under consideration for switch and where a conversion to compressed natural gas (i.e CNG) buses could possibly raise this (i.e. due to higher MJ/veh.km -see I(i) and I(j) above) the possibility of reducing fuel consumption to the ratio of 17.76/25.41 or to 70% (excluding gas compression) is worth a deeper look. If as much as 16% of the old trolley energy use rate of 2.92Kwhr/v.km, ie. 10.5MJ/v.km (electric energy) is needed to prepare fuel for each CNG bus then that's an attribution of .16 x 10.5MJ/v.km that must be added to the CNG or 1.6MJ/v.km (electric) or 1.6 x 1/.48 x 1/.975MJ (fuel) ie. 3.5MJ/v,km. thus the 25.41MJ/v.km of the CNG bus rises to 28.91 MJ/v.km for total fuel (electric and power). Some might say it is unfair to charge CNG buses with all the compression energy, while at the same time requiring the gas turbine plant to make use of pipeline high pressure for free. One should bear in mind that gas distributors waste that latent pressure energy as they expand pipeline gas down to distribution pressure. No-one is charged for that.

(h) None of that is possible without

(i) major investments in street power distribution

(ii) new power generation investment

Of these (ii) is the lesser problem (!). Private or public systems would likely compete for this if total removal of bus emissions from city streets was the objective then (i) would become a tolerable program.

III WHAT DOES ALL THIS MEAN?

(a) Assume that about 35% of the total Ontario diesel bus fuel usage and street emissions are wiped out and replaced with electric buses. Assume further that the electric power comes from gas turbine combined cycle gas fuel, plants and that these displace coal fired plants. In the annual mix of generation for Ontario Hydro, about 25% is deemed to come from fossil fueled plants (i.e. coal and gas) and the rest from hydraulic and nuclear plants.

While the motivation here is to support added electric load, it is in the nature of electric power systems that no particular load on the system can be deemed to be supplied by a particular plant type (. . unless they are **directly** connected). Hydro would verify that. If the gas turbine etc. plant was bigger than needed for TTC then it could be seen as substituting for coal plants. (To meet total power plant emissions targets it might well be much larger.) Therefore one should attribute at least 25% of the power plant emissions to the electric bus energy consumption in any minor substitution. For large scale substitution however, this analysis uses **full** attribution.

(b) There will be federal standards for emissions from gas turbine power plants and these are not yet published. They will likely coincide with U.S. standards since it's effectively a single equipment market. It is known that in simple cycle configuration and producing about 50MW, one manufacturer states these emissions:

NO_x : 0.46g/kWhr (or about .31g/kWhr in combined cycles
CO : 0.13g/kWhr (or about .9g/kWhr " " "
VOCs: 0.02g/kWhr (or about .01g/kWhr " " "

Carbon dioxide would be that associated with gas fuel of 7.5MJ/kWhr (see II(b) above). Ontario Hydro demand/supply plan quotes CO_2 production at 605g/kWhr for large 150MW size gas turbines in "simple" cycle. In combined cycle, this would drop to about 400g/kWhr (C.C. increases output by ½ for no extra fuel, therefore CO_2 would drop to 2/3). This, by the way, compares to a **modern** coal plant of 860 grams per kWhr - i.e. ½!

(c) Now to make a few comparisons:

(i) from the VHB report one finds these factors for 1990, for line 26 (urban diesel buses)

CO_2 production	70.68g/MJ
SO_2	0.40g/pass.km
NO_x2	.92g/pass.km
VOCs	0.28g/pass.km
Particulates	0.19g/pass.km
CO	1.37g/pass.km

In section I(e) it was deduced that TTC has 9.6 passengers/bus, so, if one multiplies each of the above 5 pollutant factors by 9.6, one gets at least one 'cut" at current production. Simultaneously, using TTC's average fuel consumption from I(c) and the CO_2 factor above one gets a 1990 picture of CO_2 production.

Thus: VHB Year 1990 (diesel bus, 1989 TTC)
CO_2 : 20.23MJ/veh.km x 70.68g/MJ = 1429.9g/veh.km
SO_2 : .40g/pass.km x 9.6 pass/veh = 3.64g/veh.km
NO_x : 2.92g/pass.km x 9.6 pass/veh = 28.0g/veh.km
VOCs : 0.28g/pass/km x 9.6 pass/veh = 2.7g/veh.km
Particulates : 0.19g/pass.km x 9.6 pass/veh = 1.8g/veh.km
CO : 1.37g/pass.km x 9.6 pass/veh = 13.2g/veh.km

(d) Returning to the data in III(b) and using the observations in II(e) one sees: Fuel energy consumption of trolley coach 2.19kWhr/veh.km, then one sees for trolley coaches: 2.19kWhr/veh.km ÷ .925 (for line losses) or 2.37 **generated** kWhr/veh.km. That leads to this:

CO_2 production : 2.37kWhr/veh.km x 400g/kWhr or 948g/veh.km
SO_2 production : "lower" than diesel
NO_x production : 2.37kWhr/veh.km x .31g/kWhr or .73g/veh.km
VOCs : 2.37kWhr/veh.km x .01g/kWhr or .03g/veh.km
Particulates : "very low"
CO : 2.37kWhr/veh.km x .9g/kWhr or 2.13g/veh.km

Compare:

	Diesel (1989/90)	**Electric (CCGT displacing coal)***
CO_2	1429.9g/veh.km	948g/veh.km
SO_2	3.64g/veh.km	
NO_x	28.0g/veh.km	.73g/veh.km
VOC's	2.7g/veh.km	.03g/veh.km
Particulates	1.8g/veh.km	
CO	13.2g/veh.km	2.13g/veh.km

* Combined Cycle Gas Turbines

TTC alone operated almost 100 x 10^6 vehicle kilometers in 1989. If one takes a round number of 100 x 10^6veh/km for all of Toronto, Mississauga and Hamilton as eligible for conversion to electric bus operation, one sees these reductions from current diesel operation: (per 10^8veh.km/yr) (That's about 35% of the Ontario total.)

CO_2 : (1430 - 948) x $10g^8$veh.km/a x 1kg/1000g x 1MT/1000kg
or 48,200 Metric Tons/a
SO_2 : significant reduction - little or no sulphur in gas fuel
NO_x : (28 - .73) x $10^8/10^6$ etc or 2728 MT/a
VOCs : (2.7 - .03) x $10^8/10^6$ etc or 267 MT/a
Particulates significant reduction
CO : (13.2 - 2.13) x $10^8/10^6$ etc or 1107MT/a

(e) The gas fueled bus would cause 28.91/17.76 or 1.628 times trolley fuel, ie. 60% more fuel, to be used. Therefore it just can't be as benign as the electric system outlined.

(f) Now all this pays little heed to quantifying investment costs and it is tabled for 1990, not 2005 where diesel fuel consumption is projected to be much higher . . and where emission reductions would be correspondingly greater. This should be examined. There also remains the matter of pollutants from sources of fossil fuels, through transmission to point of burning.

APPENDIX V: HIGH OCCUPANCY VEHICLES (Autos, Vans)

SUMMARY

The possible combinations of passengers and vehicles are very, very many. While intercity data is cited, it is presumed to be a partial candidate for a switch to rail, in another report.

Examining only urban private gasoline powered autos and trucks (i.e. vans), it is deduced that:

A switch of 33% of single occupant drivers in all urban auto veh.km/yr. to 8 passengers/van plus a switch of 6% of single occupant drivers of all urban auto vehicle km/year into dual occupancy vehicles would:

a) eliminate growth in $C0_2$ from urban gasoline private autos and van from 1985 to 2005, i.e. 2.531×10^6 metric tonnes/yr.

b) eliminate a further 1×10^6 metric tonnes of $C0_2$/a in year 2005 (Total 3.531×10^6 metric tonnes)

The candidacy of diesel autos and light diesel trucks was not considered as simply requiring too much time. They are viewed as lending these limited calculations a greater "catchment" potential and hence greater practicality.

IMPACT

Some Data:

Reference to high occupancy vehicles implies fuller use of automobile and passenger van seating capacity.

For example, the VHB Research Report (Table B-4, Line 6) gives vehicle energy efficiency and pollutant emissions for gasoline fueled private autos, intercity travel, as follows:

TABLE (A)

	1985	1990	1995	2000	2005
Energy MJ/Veh.Km	3.093	3.012	2.942	2.766	2.663
Vehicle use Veh.Km/a all X 10^{10}	3.18	3.40	3.79	4.05	4.41
$C0_2$ @ 67.97g/MJ in g/veh.km	210.23	204.72	199.97	188.00	181.00
$S0_2$ in g/veh.km	.08	.08	.08	.08	.08
$N0_x$ in g/veh.km	1.97	1.26	0.95	0.63	0.60
VOC's in g/veh.km	2.30	1.73	1.38	1.03	0.99
Particulates g/veh.km	0.34	0.34	0.74	0.34	0.34
C0 in g/veh.km	19.30	12.52	10.09	7.66	7.48

There is another popular and useful vehicle used privately (and publically) called the 'van'. It isn't specifically listed by VHB but in the tabulation on Page 35 of "Steering a New Course", it is shown as consuming energy:

- single occupant : 9,048 BTU/pass mile
- nine occupants : 1,094 BTU/pass mile

i.e. those extra 8 passengers are carried for a fuel use of 9 X 1094 less 9048 BTU/mi.
i.e. 798 BTU or about 100 BTU each. Putting all this in our accustomed units where 1 joule equals .000948 BTU and one Km - .62137 mil, then one sees:

- single occupant uses $\frac{9048}{.000948}$ X $\frac{.62137}{10^6}$ MJ/pass. km
or 5.93 MJ/pass. km

(i.e. about 2 X the single driver auto)

- With nine occupants, the rate becomes .716 MJ/pass.km
- Putting it another way, the incremental energy for each of the 2nd, 3rd, etc. extra occupant at 100 BTU each becomes .066 MJ/pass.km
- Thus in a van with these passengers, one arrives at these rates:

1/van5.93 MJ/pass. km		
2/van	(5.93 + .066) ÷ 2 or	3.00 MJ/pass. km
3/van	(5.93 + 2 X .066) ÷ 3 or	2.02 MJ/pass. km
4/van	(5.93 + 3 X .066) ÷ 4 or	1.53 MJ/pass. km
5/van	(5.93 + 4 X .066) ÷ 5 or	1.24 MJ/pass. km
6/van	(5.93 + 5 X .066) ÷ 6 or	1.04 MJ/pass. km
7/van	(5.93 + 6 X .066) ÷ 7 or	.90 MJ/pass. km
8/van	(5.93 + 7 X .066) ÷ 8 or	.79 MJ/pass. km
9/van	(from above)	.72 MJ/pass. km

The VHB Table B4, line 8 "private intercity light trucks" with gasoline energy use per vehicle km shows:

1985 : 5.855MJ/veh. km and usage 3.98 X 10^9 veh. km/a
1990 : 5.736MJ/veh. km and usage 4.10 " " " "
1995 : 5.407MJ/veh. km and usage 4.71 " " " "
2000 : 5.090MJ/veh. km and usage 5.41 " " " "
2005 : 4.801MJ/veh. km and usage 6.22 " " " "

Bearing in mind that the 5.93 MJ/pass. km is from 1987 data, it can be said to be approximately equivalent to the 1985 : 5.855 MJ/veh. km above. So, as a proxy for vans, it can be inferred there is a large van growth projected over 20 years: 3.98 to 6.22 billion veh. km/annum or 56%

All of the above concerns intercity movement so far as VHB data is concerned.

Turn now to urban private auto (gasoline) movements. From VHB's, line 30, one sees this.

TABLE (B)

	1985	1990	1995	2000	2005
Energy MJ/Veh. km	4.585	4.503	4.427	4.163	3.996
Vehicle Use in Veh.km/a all X 10^{10}	4.25	4.61	5.09	5.42	5.64
CO_2 @ 67.97g/MJ or g/veh. km	311.64	306.07	300.90	280.23	268.99
SO_2 in g/veh. km	.08	.08	.08	.08	.08
NO_x in g/veh. km	1.97	1.26	0.96	0.63	0.60
VOC's in g/veh. km	2.30	1.73	1.38	1.03	0.99
Particulates in g/veh. km	0.34	0.34	0.34	0.34	0.34
C0 in g/veh. km	19.30	12.52	10.09	7.66	7.48

Line 31 of the VHB tables shows private passenger light truck, urban duty as this:

	Energy MJ/veh.km	**Usage 10^9 veh. km/a**
1985	5.829	3.77
1990	5.738	3.94
1995	5.407	4.52
2000	5.090	5.19
2005	4.801	5.98

Some Observations:

The product of "MJ/veh.km" and "veh.km/a" for 1985 and represents total energy and will also give an idea or index of how the carbon dioxide output of autos and vans (i.e. light trucks) is changing. (all X 10^9)

Inter City Autos
19853.093 x 3.18 x 10 =98.36
2005 2.663 x 4.41 x 10 =117.44 i.e. up 19%
Change: 19.08

Urban Autos
19854.585 x 4.25 x 10 =194.86
20053.996 x 5.64 x 10 =225.37 up 16%
Change: 30.51

Inter City Vans
19855.855 x 3.98 = 23.30
20054.801 x 6.22 =29.86 up 29%
Change: 6.56

Urban Vans
19855.829 x 3.77 =21.98
20054.801 x 5.98 =28.71 up 31%
Change: 6.73

(The "10" factor is to recognize that the vehicle demand number, eg. 3.18 for autos is X 10^{10} while those for vans is 10^{9})

Now it hasn't been given that the VHB data for light trucks means "vans", it has only been inferred that the data is a proxy for vans.

In a ranking of worst down to least there would be - urban autos
- inter city autos
- vans - either

It is not possible to say whether Oakville-Toronto is "urban" or "inter city", likewise Scarborough-Oshawa, so a macro approach to vehicle km will be tried.

Taking the total energy usage (all x 10^{11} MJ/a)

	1985	**1990**	**1995**	**2000**	**2005**
Inter city, private auto, gasoline powered	9.83	1.02	1.11	1.1	1.17
Inter city, private light trucks, gasoline powered	.233	.235	.255	.275	.290
Sub Total	1.216	1.255	1.365	1.395	1.460
Urban, private auto, gasoline powered	1.95	2.08	2.25	2.26	2.37
Urban, private light trucks, gasoline powered	.220	.226	.245	.264	.287
Sub Total	2.17	2.306	2.495	2.524	2.657
Full Total **(ALL Energy)**	3.386 (6.15)	3.561 (6.41)	3.860 (7.02)	3.919 (7.44)	4.117 (7.94)

What must be switched to remove one million metric tons of CO_2 by 2005? At a production rate of 67.97g/MJ for gasoline powered vehicles, the energy use reduction required is 1 x 10^6 MT x 1000KG/MT x 1000g/KG x 1/67.97g/MJ or 14.7 x 10^9MJ/a i.e. .147 x 10^{11}MJ/a.

If urban van and auto energy would be 2.657 x 10^{11}MJ/a in 2005 as noted above, then the target .147 x 10^{11} is only 5% of that total. That is to say that if 5% of all single occupant (in proportion to auto/van usage) vehicle drivers pooled with another 5%, then 1 x 10^6MT/a of CO_2 would be eliminated. If this was confined to urban autos, the target .147 is .147/2.33 or 6.3% of urban autos energy usage so 6.3% would "have to" pool with another 6.3% (or with some mixture of vans and autos).

If one was to eliminate the whole growth of "urban" auto and van CO_2 production then from the earlier tables one must eliminate (30.51 plus 6.73) x 10^9MJ/a i.e. 3.724 x 10^{11}MJ/a of usage/ That's only .3724/2.657 or 14% of combined energy usage. This could be done as in the previous example and/or by more intensive pooling.

For example, for every 3 single occupancy auto drivers, who join a single driver van (i.e. 4 total) one saves (1985 VHB numbers) 3 x 3.093MJ/veh.km for idled vehicles or 9.279MJ/trip.km and one consumes 1.53MJ/pass.km or 6.12MJ/trip.km. That's a saving of

3.16MJ/trip.km for 4. To save the .3724 x 10^{11}MJ/a one would need to achieve $\frac{.3724 \times 10^{11}\text{MJ}}{3.16\text{MJ/trip.km}}$ or 1.178 x 10^{10} trip km/year for four people in one van. Actually, the 1.178 x 10^{10} would be a little higher in 2005 because of projected increasing fuel efficiency of the vehicle. Decreased energy consumption of 10% or so is projected by VHB so the trip.km would have to rise by the ratio 10/9 or to 1.310 x 10^{10} trip.km for four. That's equivalent to reducing single occupancy auto usage by 3 x 1.310 x 10^{10} veh.km/a or 3.93 x 10^{10}. That's a mighty $\frac{3.93}{5.69}$ or 69% of all auto veh.km/a and is likely a very unrealistic target.

If one raised the van load to six passengers then the picture changes:
5 x 3.093MJ/veh.km saved from idled vehicles or 15.465MJ/trip.km and consumption becomes 1.04MJ/pass.km or for six - 6.24MJ/trip.km. That's a saving of 9.225MJ/trip.km for six. That's 3x the saving with only four!

Then to save the same $\frac{.3724 \times 10^{11}\text{MJ/a}}{9.225\text{MJ/trip.km}}$ or .403 x 10^{10} trip.km/a with six passengers/vans.
As before, due to projected efficiency improvements, the .403 would have to end up as 10/9 x .403 or .449 x 10^{10} trip.km/annum. Again this means reducing single occupance auto usage by .449 x 10^{10} x 5 or 2.245 x 10^{10} veh.km/yr. That's 39% of the urban auto veh.km/a (i.e. 5.69 x 10^{10}).

With 8/van, one gets these numbers:
- idled auto savings 7 x 3.093MJ/veh.km or 21.651MJ/trip.km
- van fuel energy 8 x .79MJ/trip.km or 6.32

Saving: 15.33MJ/trip.km

That required $\frac{.3724 \times 10^{11}}{15.33}$ etc or .242 x 10^{10}veh.km/a with 8/van.
Grossing up again, that's .269 x 10^{10} etc. That means reducing single occupancy auto usage by .269 x 10^{10} x 7 or 1.883 x 10^{10}veh.km/a or 33% of the 5.69 x 10^{10} total.

Summary

Clearly then, if 33% of the one driver auto km/a could move to 8 passenger vans, one would offset the whole of the 20 years rise, i.e. 2.531 x 10^6MT, in **urban** auto and van CO_2 production!

If another 6% of single driver auto veh.km/a pooled with another 6%, there would be a net reduction of a further million metric tons/years!

That's a total of 3.53 x 10^6 metric tons.

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